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Astronomy
Sky Guide
2009
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The explosive deaths of Sun-like stars p. 38

December 2008

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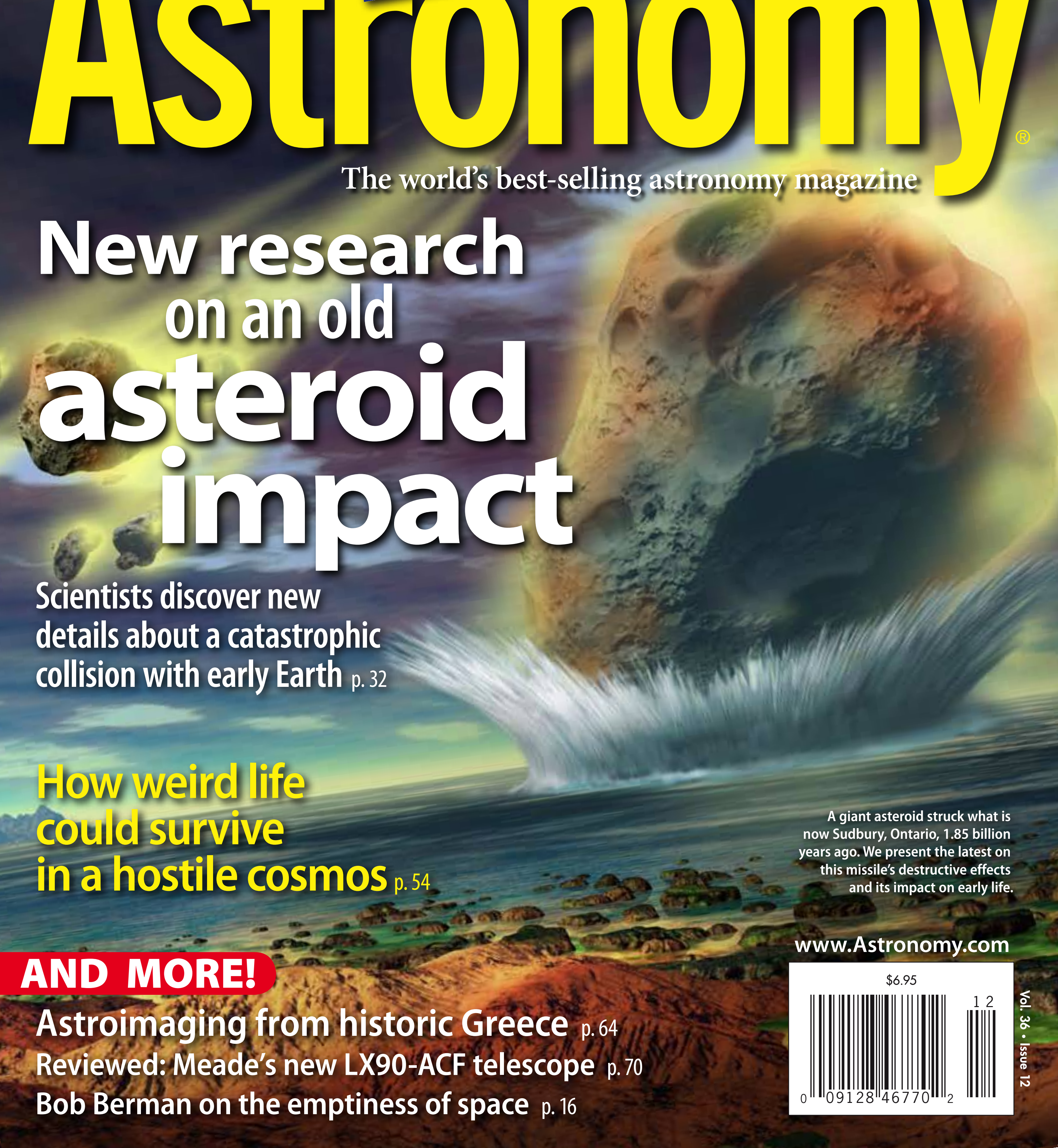

New research on an old asteroid impact

Scientists discover new details about a catastrophic collision with early Earth p. 32

How weird life could survive in a hostile cosmos p. 54

A giant asteroid struck what is now Sudbury, Ontario, 1.85 billion years ago. We present the latest on this missile's destructive effects and its impact on early life.

AND MORE!

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Reviewed: Meade's new LX90-ACF telescope p. 70

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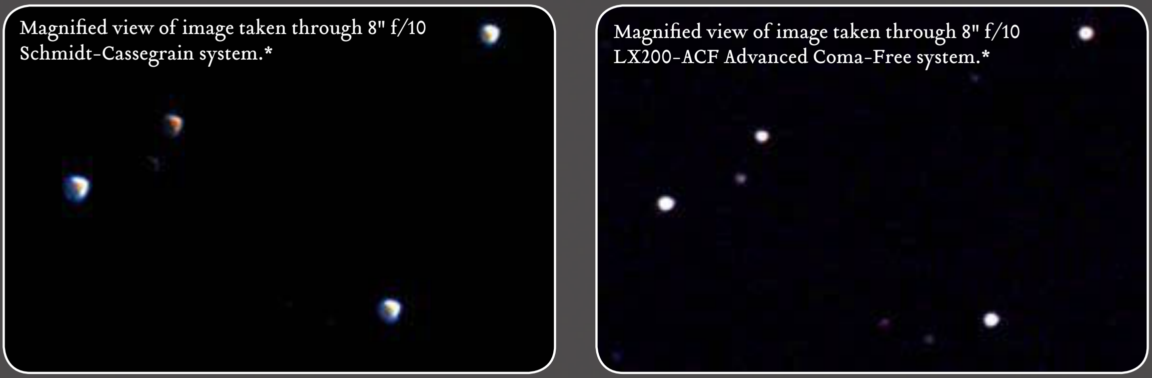

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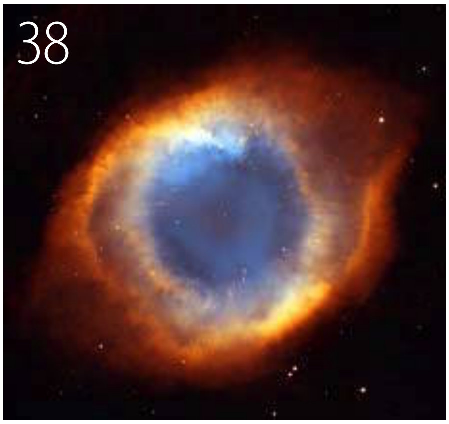

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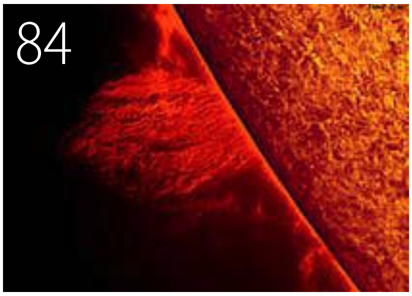

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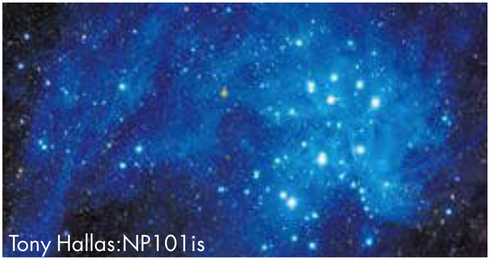
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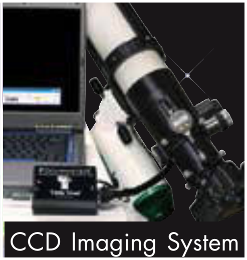
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This month in *Astronomy*

Welcoming *Astronomy's* new editors

by David J. Eicher

Late last summer three new members joined *Astronomy*'s staff, and I want to introduce them to you. Two of them are returning employees who have been with the magazine in the past. Longtime readers may recognize the byline of Liz Kruesi, who returned to school after a stint at the magazine a couple of years ago and now has come back to rejoin us. As an associate editor, Liz will be involved with editing and writing feature stories about her favorite topic, cosmology, among a host of other things.

Liz graduated from Lawrence University in Appleton, Wisconsin, with a physics major and an English minor. She is a renaissance woman. While earning her degree, she was involved with dance performances, studying at Columbia University's Biosphere 2, and completing two internships for the University of Chicago Physics Department. A native of Park Ridge, Illinois, Liz is an avid astronomy enthusiast, and she looks forward to again applying her knowledge to the pages of *Astronomy*. Welcome back, Liz!

Another old friend returning to the staff began his career as an intern at *Astronomy* until he left that position to run public relations for Kalmbach Publishing Co. in 2006. Matt Quandt was an enthusiastic powerhouse for the magazine, and returns now as our online editor. He will split his time between that task and conducting the public relations duties for the company.

Online Editor Matt Quandt

Astronomy: William Zuback, Jim Forbes

Associate Editor Liz Kruesi (left), and Copy Editor Karri Ferron

Away from work, Matt and his wife look forward to sharing their enthusiasm for Marquette University men's basketball and University of Wisconsin football with their 1-year-old daughter. Matt hopes that by the time you read this, the Chicago Cubs will have won their first World Series since 1908 — a rare occurrence even astronomers can appreciate.

The final recent addition to our staff is a new one — a brilliant young mind fresh from school. Copy Editor Karri Ferron graduated from the University of Missouri in May, where she majored in journalism and minored in business. She was awarded the Walter Williams scholarship and earned membership in Kappa Tau Alpha (the national journalism honor society) and Golden Key International Honour Society.

Karri worked on one newspaper and three magazines while pursuing her degree. She studied abroad in 2007 with Imperial College, London, and interned with *Professional Beauty* magazine during that time.

A native of Mequon, Wisconsin, Karri describes herself as a huge fan of the Green Bay Packers. Go, Pack, Go!

Please help me welcome Liz, Matt, and Karri. We look forward to their many contributions to the magazine and the web site, which they will make both finer and more vibrant in the days ahead.

Yours truly,

David J. Eicher
Editor

Astronomy
Volume 36, Number 12

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December web extras

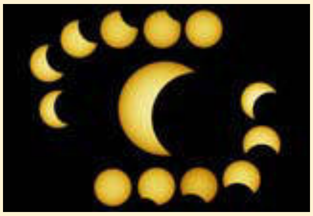
Web extras at www.Astronomy.com/toc bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"How life could thrive on hostile worlds" p. 54
Watch a video of tube-worm colonies at a hydrothermal vent.

"Astroimaging over ancient Greece" p. 64
See a gallery featuring more of Anthony Ayiomamitis' images.

"X-rated astronomy" p. 74
Read more about sensible housing for your telescope.

"It's a Wonderful Star" p. 76
Learn how to estimate Mira's magnitude.



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Senior Editor Michael E. Bakich reveals his top 10 deep-sky targets.

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Editors put their spin on astronomy events in the staff blog. You can share your opinions, too. Read all of the editors' blogs at www.Astronomy.com/blog.

1 OH, THE PEOPLE YOU'LL MEET ON *ASTRONOMY* TOURS.
I've met corporate executives, small-business owners, professional photographers, and lots of others. **BY MICHAEL E. BAKICH**

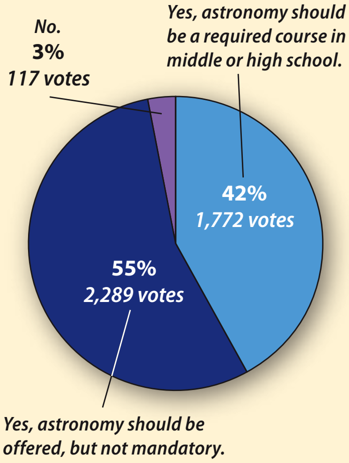
2 MERCURY'S MASTER MAPPER
Robert Gaskell is creating super-detailed maps of Mercury based on MESSENGER images. **BY DANIEL PENDICK**

3 RUSSIA, GEORGIA, AND THE INTERNATIONAL SPACE STATION
What happens if our relations with Russia break off completely and we lose access to Soyuz rockets? **BY DICK McNALLY**

Soyuz spacecraft

Online poll results

Should astronomy be part of middle- and high-school curriculums?



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The Bug Nebula in Scorpius

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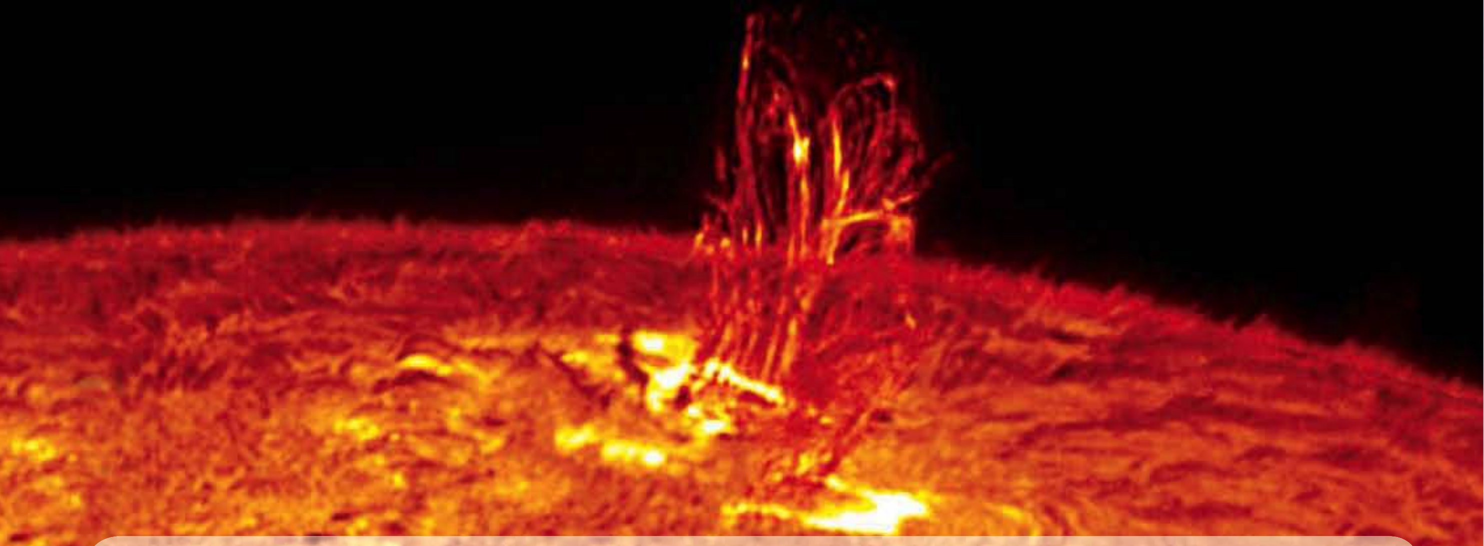

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Uranus: ice giant or gas giant?

In his August column, Glenn Chaple refers to Uranus as a "gas giant." It's my understanding that Uranus and Neptune have been reclassified as "ice giants" because they have large, icy cores and relatively shallow atmospheres as compared to true gas giants, which have deep atmospheres and small or no cores.

Are the terms gas giant and ice giant being used interchangeably? If not, which type is Uranus? — **Kim Boriskin,** Bellingham, Massachusetts

For decades, the four outer planets — Jupiter, Saturn, Uranus, and Neptune — have been known as the "gas giants" because they are primarily composed of hydrogen and helium. The term is misleading because only the upper parts of the atmospheres of the four are in a gaseous state. Farther down, intense pressure compresses these gases into a slushy liquid.

Recently, some astronomers have been referring to Uranus and Neptune as "ice giants," citing a higher quantity of "ices" (water, ammonia, and methane) in their composition. Generally, however, we still label all four planets "gas giants."
— **Glenn Chaple,** Contributing Editor

A questionable future

I just read Abraham Loeb's "Is there an end to cosmology?" (August 2008). A few months ago, I read a similar article in *Scientific American* by Lawrence Krauss and Robert Scherrer (the peer-reviewed journal version that Loeb references in his article). These articles, and others like them (such as *Astronomy*'s article about the eventual merger of the Milky Way and Andromeda galaxies, "Our galaxy's date with destruction" [June 2008]), make an unsupportable assumption about the future of the human race.

Our rise to dominance in a few million years and our ability to step off the face of this planet into a tiny fragment of the cosmos just in the past 50 years is without precedent in the history of life on Earth. But, as astounding as that is, there is no reason to believe that our species, or anything resembling it, will still be here billions of years from now to witness the end of cosmology or the merger of our galaxy with its neighbor.

The first stirring of life began only 3.8 billion years ago. The first multicelled organisms came into existence only 1.8 billion years ago and mammals a mere 65 million years ago. The vast majority of species (99.9 percent by some estimates) have long since gone extinct. By what logic, given the history of life on our planet, should we assume that we, or anything like us, are going to be here in a few billion years? The evidence up to now suggests that the end of our species will come long before the end of cosmology.
— **Ian Dodd,** Culver City, California

Illustrator applause

Reading "Backstage at *Astronomy*" (August 2008) was an even greater delight after having deciphered what I could of the illustration on page 29 ("Is there an end to cosmology?"). How creative were Theo Cobb and Chuck Braasch to weave in allusions to *Star Trek*, *Babylon 5*, *The Hitchhiker's Guide to the Galaxy*, *The Black Hole*, *R.U.R.*, and *E.T.* (There must be some Asimov, Clarke, Heinlein, and *Futurama* in there somewhere!) My congratulations and thanks to them both. And how good to be able to put a face to Braasch and some of your other staffers! Thanks for humanizing your magazine. — **Christopher C. Tew,** Greensboro, North Carolina

In need of direction

I'm confused about something in the August issue of *Astronomy*. In "Staring contest," Bob Berman says we are zooming toward Deneb. But in "The King's astronomer," Glenn Chaple says the solar system is moving in the direction of the constellation Hercules.

Because Deneb is in the constellation Cygnus, I don't see how we can be heading toward two different constellations at the same time. — **Walter B. Larew,** Falls Church, Virginia

This is one of those rare and wonderful times when everyone is right. As we whirl around the galactic center, we follow Deneb. We head in that direction at a brisk 144 miles per second. At the same time, relative to all the stars around us moving that same way, we display a little lazy sideways drifting toward Hercules at only a dozen or so miles per second. Thus, the latter is correct if our reference frame is the body of stars surrounding us and we are interested in how our motion deviates from theirs. — **Bob Berman,** Contributing Editor

Uranus is considered both a gas giant and an ice giant because it has an icy layer beneath its gaseous atmosphere. NASA/ESA/M. Showalter (SETI Institute)

Corrections

In *Astronomy*'s July 2008 "Path of the planets" pullout, Jupiter's distance from the Sun should read 5.176 AU, and its distance from Earth should be 4.164 AU.
— ***Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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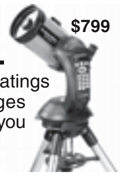

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Astronomy magazine said "everyone should own" the $359 Astro-Tech AT66ED.

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AT66ED
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A review in *Astronomy* said "While I'd normally have reservations about recommending a scope with less than 3 inches of aperture, every once in a while there comes a product everyone should own. This apochromatic doublet is just such a beast . . . The short focal length makes it a wonderful tool for scanning the Milky Way, and its small aperture and FPL-51 glass let you crank up the magnification on the Moon without false color becoming too intrusive. The AT66ED can serve as a great grab-and-go scope, a fine little astrograph, a superfinder scope, and a daytime spotting scope."

The **Astro-Tech AT66ED** has ED doublet optics; rotating dual-speed focuser; compression ring eyepiece holder; case; and a mounting shoe that fits Astro-Tech, Celestron, Meade, and Vixen mounts. It comes in black, white, red, blue, or green.

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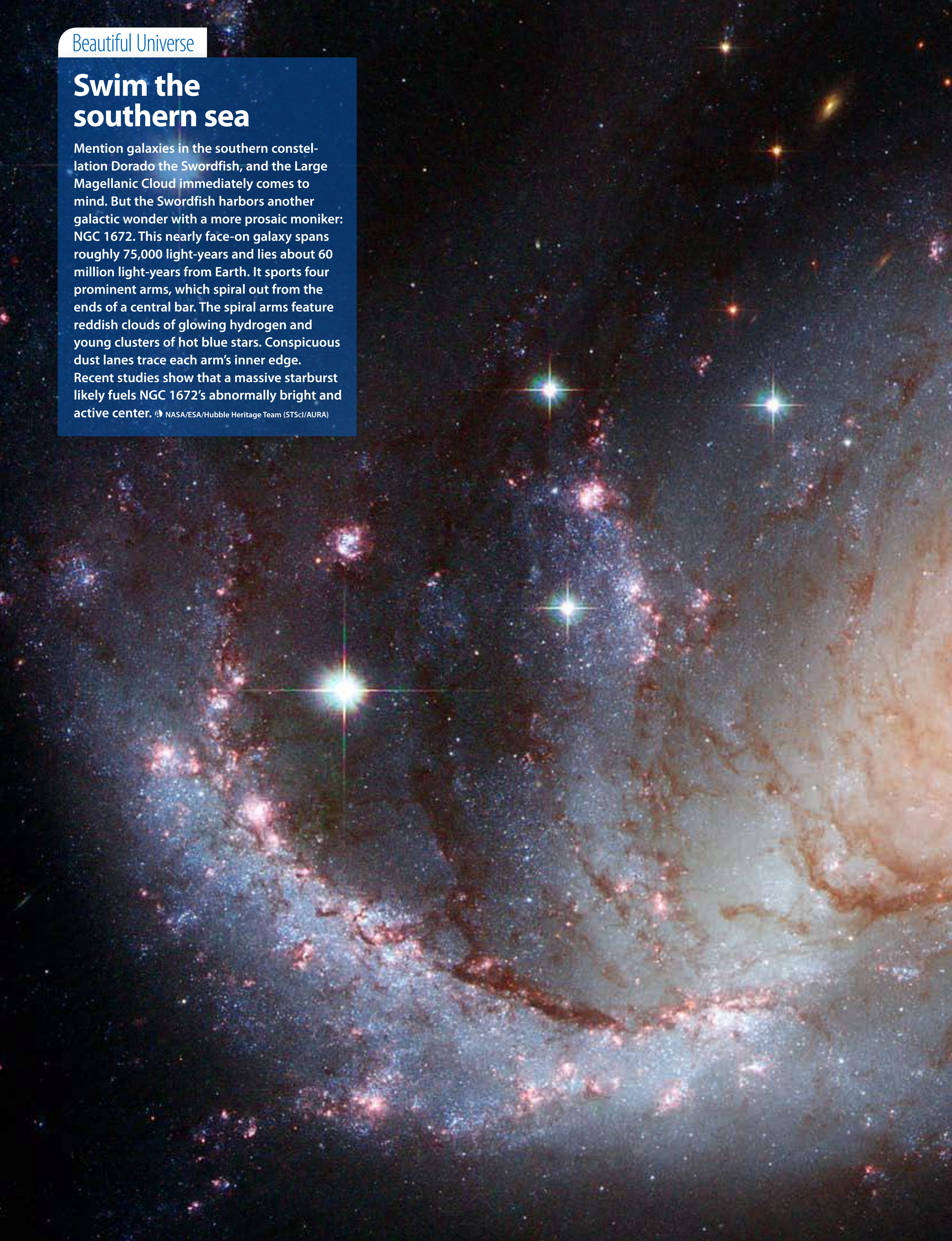

Swim the southern sea

Mention galaxies in the southern constellation Dorado the Swordfish, and the Large Magellanic Cloud immediately comes to mind. But the Swordfish harbors another galactic wonder with a more prosaic moniker: NGC 1672. This nearly face-on galaxy spans roughly 75,000 light-years and lies about 60 million light-years from Earth. It sports four prominent arms, which spiral out from the ends of a central bar. The spiral arms feature reddish clouds of glowing hydrogen and young clusters of hot blue stars. Conspicuous dust lanes trace each arm's inner edge. Recent studies show that a massive starburst likely fuels NGC 1672's abnormally bright and active center. NASA/ESA/Hubble Heritage Team (STScI/AURA)

Strange Universe

by Bob Berman

Plenty of nothing

Space is as important as the solid matter it surrounds.

This darkest month naturally invokes the mood and blackness of space. But space is an odd thing. It's widely envisioned as a wall-less container that bounds the universe — and yet is hard to examine.

When I was in college, they taught us that space is mere nothingness. A vacuum. What could be simpler? Then came Alan Guth's 1979 Big Bang inflation theory and a theoretical new "false vacuum" out of which sprang gravity, matter, and, eventually, the Miami Dolphins. Now it seems space has a powerful anti-gravity property that dominates everything. A surprise and a mystery, but not totally out of the blue: Quantum Electrodynamic (QED) theory had earlier predicted that even total emptiness must have properties. Mind-numbing? Then perhaps it's high time for a CliffsNotes review of … nothing.

Your bedroom is not an ideal place to contemplate vacuums. We live in an unusually dense environment; human fingertips alone tingle with a trillion quintillion atoms, and forget all the unloved fat diligently added at fast-food emporiums. Over 99.9 percent of our body mass consists solely of protons and neutrons, each exactly as dense as a neutron star. But these hyper-compact particles are each a gnat in an empty stadium. If we could suck out all the wasteful space within and between our body atoms and pack the entire human race down to its actual solids, it could all be presented with trumpets and fanfare as a single sugar cube weighing 500 million tons. Remove all our hot air and Homo sapiens is 1 cc, ready to party.

That you can pick up a fork without a forklift correctly evokes the immense emptiness surrounding all of a bosun's bosons. Even entire atoms with their decadently extravagant space are smaller than most of us imagine. Each has the same proportional size to an orange that the orange has to Earth. Thus, solid matter is quite empty, enough to let any couch potato fall through the couch, then through the floor as well. The powerful pressure preventing this comes not from your body particles meeting the floor's, but its electrical fields encountering yours. It's a first hint that energy is more significant than so-called visible solids.

The tiny particles within all this empty space dart around wildly. Your body's protons jiggle frenetically at one-third the speed of light; the much larger molecules they inhabit merely break the sound barrier at a lethargic Mach 1.5, or 1,100 mph (1,800 km/h).

Time will tell if "nothing" can indeed explain everything.

Things are only slightly calmer in the frozen vacuums of distant space. QED says "virtual particles" continuously snap, crackle, and pop in and out of this nothingness, though this has never been observed. Moreover, nearby energy fields might let evanescent particles borrow some energy and become permanently real, like Pinocchio. Indeed, the Big Bang, many believe, was a larger version of this phenomenon.

Some cosmologists think an unstable rogue vacuum — unlike ordinary, well-behaved vacuums — exploded in an expanding frenzy of energy and gravity to create the entire universe. Leftover bits of this theoretical "false vacuum" may forever "seed" countless other universes as well. It all sounds reasonable today: The cosmos' puzzling acceleration, which began 6 billion years ago, suggests runaway vacuum energy (dark energy) began exerting dominance over matter. Once responsible for the inflation that jump-started the infant cosmic expansion, negative vacuum pressure might be manifesting anew, now that gravity has grown too diluted to counteract it.

We discussed the hidden power of this vacuum energy — often called z-point energy — on this page in March 2006. For now, there's the issue of how we see and define empty space. Robert Lanza, M.D. and professor at Wake Forest University, has written a book to be published this June, arguing that space and time are strictly biological constructions with no independent existence. (Full disclosure: I'm the coauthor.) According to this view, time has no external reality, but is rather a tool of animal perception that allows us to make sense of things and put events into usable, practical forms.

Space is likewise a biologically based ordering, or method of perception. One person might focus on a waterfall's droplets; another might see the cascade as a single entity. Definitions, habits, and perceptions play a greater role than any true cut-off points — in a cosmos where energy fields dominate and objects only appear solid, where even these solids are forms of energy, and where, in any case, things come and go from the fields.

We're back where we started, on a cold December night in a universe that seems almost entirely empty, but whose vacuity seethes with inconceivable power. Did the Big Bang merely manifest as a minor blip from this unseen, all-pervasive field?

Time will tell if "nothing" can indeed explain everything. Even if so, our work will only just begin. There's more to the invisible than meets the eye.

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Secret Sky

by Stephen James O'Meara

Defect or discovery?

Nearly 200 years before their identification, William Herschel suspected uranian rings.

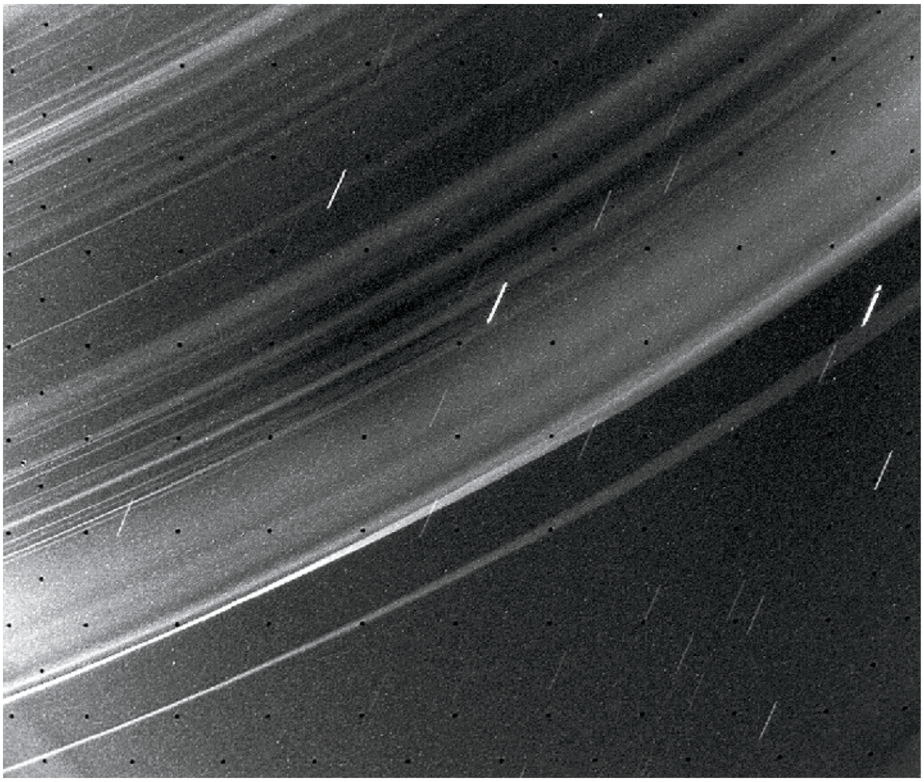
What I'm about to tell you is not new. Namely, that the German-born British observer Sir William Herschel (1738–1822) *suspected* rings around Uranus 190 years before astronomers clearly identified them in 1977. It's a fascinating historical account (and mystery) that brings to mind some of the physical, psychological, and optical factors that still influence us today in what we see (or believe we see) through the eyepiece. This month, we'll focus mainly on the optical factors.

Amateur astronomer Barbara Wilson of Houston, Texas, inspired my interest in this hotly debated topic. The controversy stems from *The Scientific Papers of Sir William Herschel*, which the Royal Society and Royal Astronomical Society published jointly in 1912. In it, Herschel includes his observations from 1787 to 1792 "tending to the Discovery of one or more Rings of the Georgian Planet."

The Georgian Planet is Uranus — a world Herschel discovered March 13, 1781, and wanted to name in honor of his patron, King George III. Six years later, on March 4, 1787, Herschel turned his large 20-foot reflector of 18.7-inch aperture to the new planet and saw something curious: "When I see [Uranus] most distinctly, it appears to have double, opposite points … perhaps a double ring; that is, two rings, at rectangles to each other."

Herschel saw the same appearance of the "rings" the next night, and again on March 7, when, using powers ranging from 600x to 1200x, he measured their relative positions. What Herschel saw was two opposing "projecting points" at right angles to one another. One pair was "large and blunt"; the other pair was "small and less blunt."

One night later, however, he wrote that these "projecting points" were "probably deceptions." Indeed, on March 16, 1789, after 2 years of monitoring the planet, Herschel began to suspect that the projections were an artifact produced by his mirror. On this night, the questioning observer turned his speculum mirror "90° round," and entered the following note: "A certain appearance, owing to a defect which [the mirror] has contracted by exposure to the air since it was made, is gone with it; … but the suspected ring remains in the place where I saw it last."



Voyager 2 took the first close-up shots of the uranian rings in 1986, almost 10 years after astronomers identified them and nearly 200 years after Herschel first suspected their existence. JPL

An "optical" illusion?

What's intriguing about Herschel's ring observations is that they began only a few months after he changed the optical configuration of his 20-foot reflector. When he started using this instrument in 1783, he observed at the telescope's Newtonian focus. After some experimenting, though, Herschel discarded the secondary mirror altogether. Instead, he tilted the primary so that its light came to an unobstructed focus at the front end of the telescope (see "Herschel's telescope configurations," page 19).

This "front-end" (or Herschelian) configuration also removed the light loss from a second reflection off a speculum mirror. The result was an increase in light-gathering power by some 30 percent. "[I] found the image as good as at the side." Herschel wrote. "The light is incomparably more brilliant."

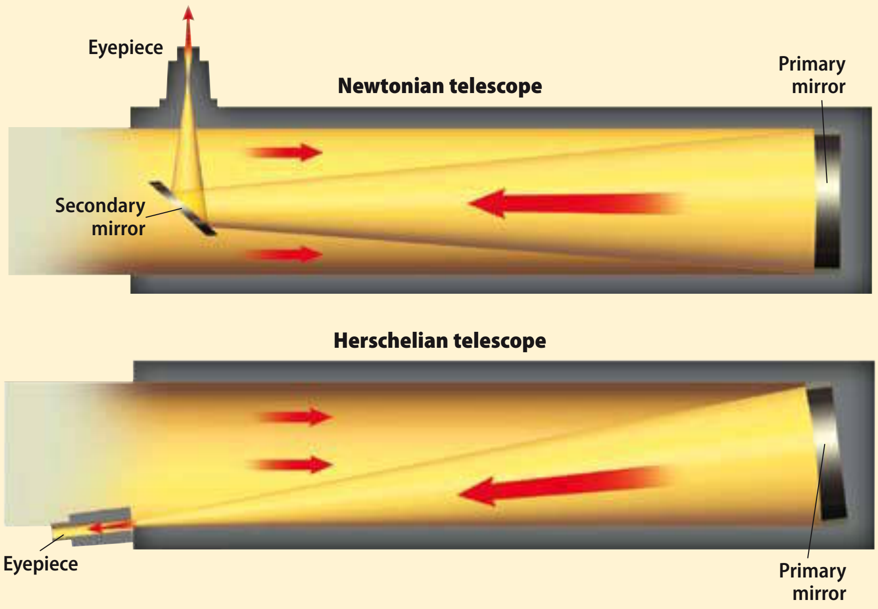
Herschel began observing at the front end September 22, 1786. A little more than 5 months later, he suspected uranian rings. But were they rings?

Unknown to Herschel, his "front-view" configuration caused aberrations in the final image. The most serious of which was "astigmatism" (which means "no spot").

By tilting the primary mirror, Herschel created an asymmetrical optical system — one that would distort the size and shape of the object being observed depending on the point of focus. If the object is just inside or outside of focus, it will appear either as a short horizontal or short vertical line; the two opposing views being perpendicular to one another. (Speaking from experience, the best way to observe a planet through Earth's ever-changing atmosphere is to continually turn the focus knob, slightly in and out of focus, in an attempt to keep the planet sharp.)

Interestingly, Herschel's measurements of his double "ring" show them to be exactly 90° apart! One could argue, then, that the rings are nothing more than ghostly artifacts created by an imperfect optical system and a twist of the wrist.

Herschel's telescope configurations



Herschel experimented with different telescope designs, starting with the Newtonian type, which has a parabolic primary mirror and a flat secondary mirror. But months before he first spotted the uranian "rings," he removed the secondary mirror and tilted the primary mirror, creating a "front-view" configuration. This system increased the telescope's light-gathering power, but it also caused aberrations in the image. *Astronomy:* Jay Smith

Ghost in the machine

So why didn't the ring move when Herschel rotated his mirror March 16, 1789, but his suspected defect did?

First, the defect Herschel suspected may not have been due to a scratch in the mirror (as he later informs us). It may have been an aberration created by an astigmatic primary mirror. Modern tests of some of Herschel's mirrors (including one of those used in his large 20-foot reflector) have, indeed, shown some astigmatism. If an astigmatic mirror is rotated 90°, the aberration will move in concert with the mirror. And this is exactly what happened when Herschel rotated the mirror March 16, 1789.

Rotating the mirror, however, would not have corrected the astigmatism produced by Herschel's front-view system; when a mirror is rotated, the system (geometrical) aberration remains in the same place — as did Herschel's suspected "ring." Herschel, then, may have been dealing with two types of artifacts — geometrical and optical.

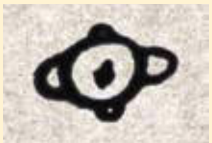
So the great observer's struggle to identify and confirm a uranian ring may have been plagued by his genius (switching to the front-view optical system to gain light-gathering power) and his ignorance of the system's inherent faults.

Indeed, when optical engineer Scott Milligan of Hubbardston, Massachusetts, modeled Herschel's "front-view" system, he found that it created large amounts of both coma and astigmatism in approximately equal magnitudes — large enough to render stars as blurred, triangular blobs some 14 arcseconds in diameter.

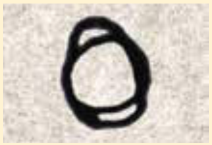
"It is fair to conclude that even an unmagnified (i.e., eyepiece removed) view would start to reveal the aberrations present in the image," Milligan says. "Looking at the results gave me an increased feeling of respect for what Herschel was able to accomplish, despite the limits of the technology available to him in his day."

The argument isn't over. Next month, I'll dive deeper into this mystery.

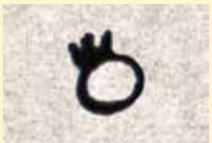
Herschel's observations of Uranus



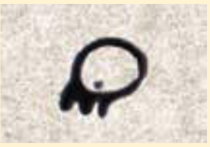
Suspected rings appearing as two projecting points.



Suspected ring, February 22 and March 16, 1789.



Suspected defect after rotating mirror, March 16, 1789.



Suspected defect before rotating mirror, February 22, 1789.

In 1787, six years after he discovered Uranus, Herschel began to suspect rings around the Georgian Planet. At first he saw two opposing "projecting points" that ran perpendicular to one another, which he thought could be a "double ring."

But after 2 years of observing, Herschel began to question his suspicion, thinking a mirror defect could have produced artificial rings. To test this, he turned his telescope's primary mirror "90° round" and found that the observed artifact followed. But the supposed ring did not move with the rotated mirror.

Herschel's observations and sketches of Uranus appear in *The Scientific Papers of Sir William Herschel*. Uranus ring sketches: *The Scientific Papers of Sir William Herschel*

Border guard Chile will pay France $72 million for a satellite to monitor its borders and assist during natural disasters. The launch is planned for 2010.

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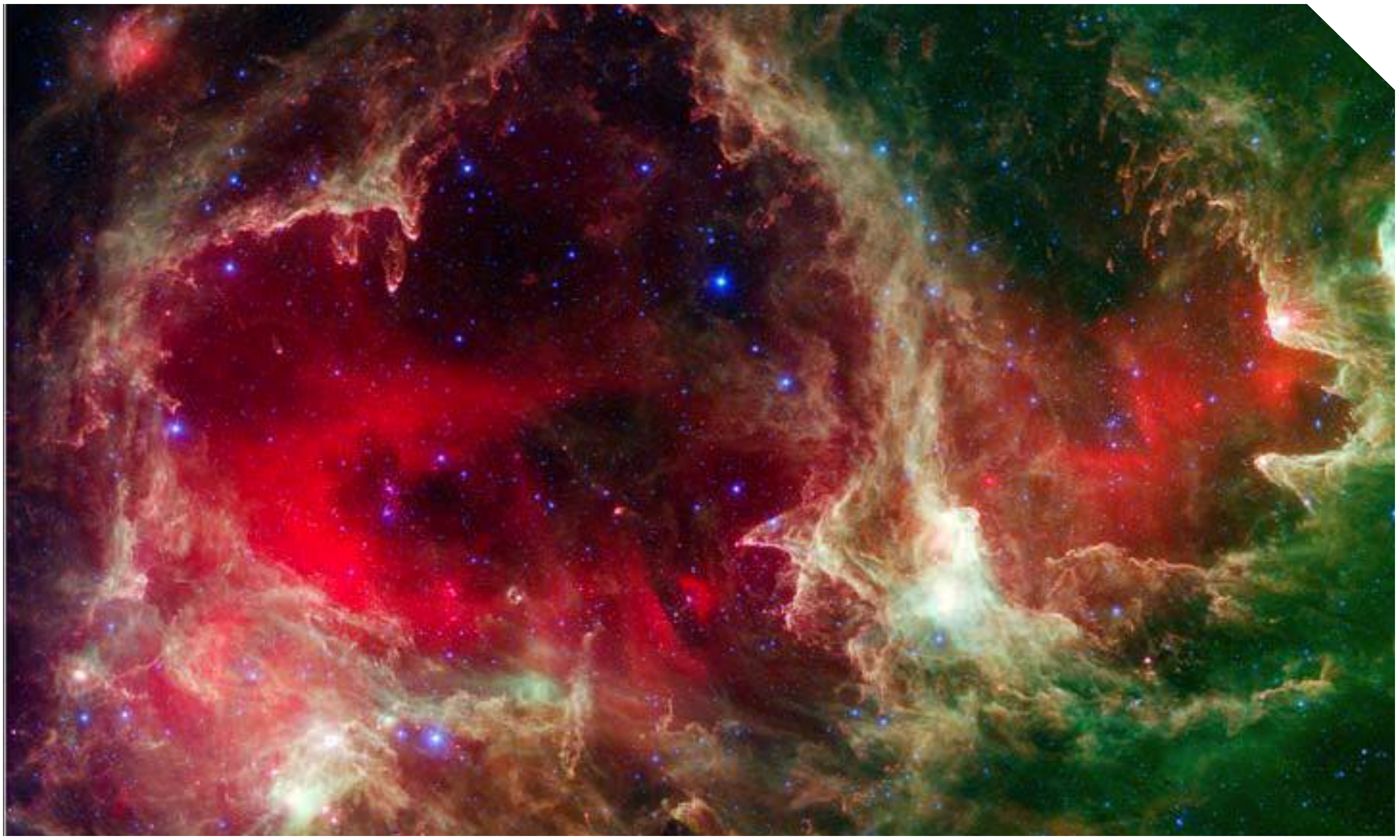

NASA/JPL-Caltech/Harvard-Smithsonian CfA

Family portrait. This infrared image by the Spitzer Space Telescope captures multiple generations of suns shining from the W5 star-forming cloud.

22 Study explains meteorite origins

24 Lunar crater is older and possibly icier

26 Cluster crash-up reveals dark matter

28 High-tech skin keeps satellites cool

Spitzer snaps dusty family portrait

NASA unveiled a stunning portrait of star birth in a massive cloud of dust and gas to commemorate the 5-year anniversary of the Spitzer Space Telescope's launch. The observatory's infrared sensors peered deep into the cloud, called W5, to reveal multiple generations of stars shining amid vast cavities. The image offers some of the best evidence yet to support a leading theory of what triggers star birth in regions like W5, astronomers reported December 1 in *The Astrophysical Journal*.

The oldest stars in the cloud appear as blue dots in the centers of two cavities. (Blue stars visible elsewhere in W5 lie in the distant background, not within the cloud.) Younger stars shine at the edges of the cavities or at the tips of dust pillars. The green zones mark the densest parts in the cloud; red coloring in the cavities indicates more thinly spread dust.

Radiation and outflowing "stellar winds" from massive, hyperactive stars carved the cavities. According to the theory of "triggered star formation," pressure exerted on gas as the cavities formed triggered successive generations of stars, with the oldest stars located the greatest distance from the cavities' centers. And this is just what scientists found when examining the Spitzer image of W5. — **DANIEL PENDICK**

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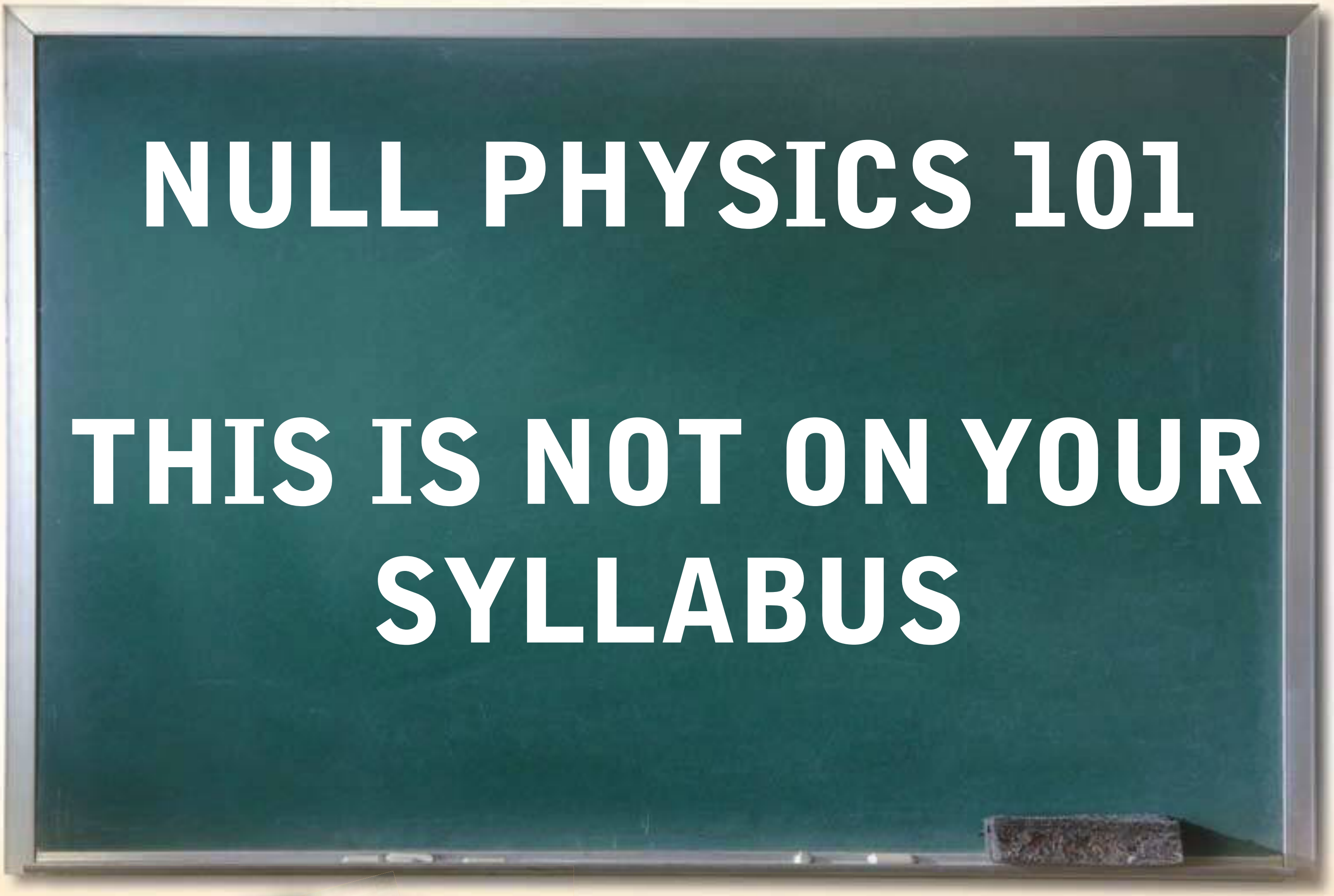

NULL PHYSICS 101

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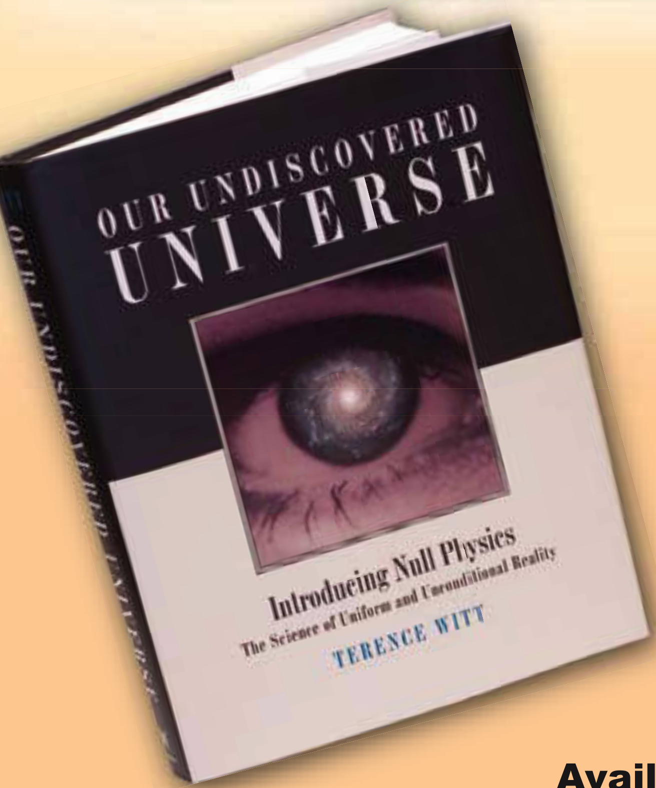
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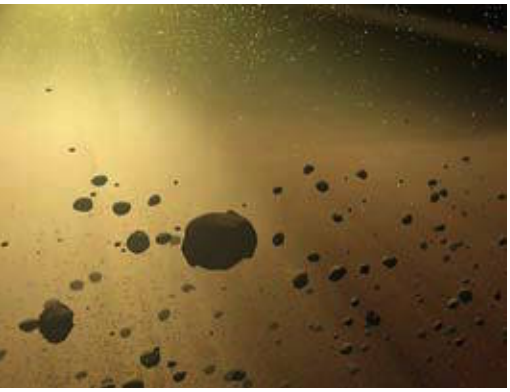


NASA/JPL-Caltech/T. Pyle (SSC)

Space-rock reservoir. In this artist's rendering, asteroids orbit the Sun in the main belt between Mars and Jupiter. New research says this region supplies most meteorites that fall to Earth.

Study explains meteorite origins

Most meteorites that fall on Earth are fragments produced by asteroid collisions. Oddly, most of the meteorites have compositions unlike those of the closest asteroid population — near-Earth asteroids, or NEAs. So where do Earth's meteorites come from, and how do they get here? Reporting August 14 in *Nature*, astronomers think they have the answers.

A team led by MIT planetary scientist Richard Binzel analyzed a large number of NEAs based on the unique mix of wavelengths of light they reflect or absorb. The researchers determined that most NEAs are similar in composition to meteorites called LL chondrites, which represent only 8 percent of meteorites found on Earth.

However, asteroids from the main belt (between Mars and Jupiter) are more varied in composition, like the space rocks that fall to Earth. This suggests the main belt is the source of most earthly meteorites. How do they get here?

Binzel and his colleagues think the meteorites travel to Earth thanks to the Yarkovsky effect, which perturbs asteroid orbits because of the way they absorb and later radiate the Sun's heat. The radiation deflects the asteroids toward Earth.

The Yarkovsky effect gives a stronger push to asteroids less than about 3 feet (1 meter) in diameter. Such debris is plentiful in the main belt, making it possible to supply Earth with meteorites, given enough time for the Yarkovsky effect to work its magic. — **MEGAN McCHAIN**

Eyewitness to Apollo 8: A personal memoir

Apollo 8 image: NASA; inset courtesy James Oberg

Witness to history. Binoculars at the ready, James Oberg (inset) watches the launch of Apollo 8 (above), which slung astronauts around the Moon for the first time.

Forty years ago this month, I witnessed the historic Apollo 8 mission that took humans for a trip around the Moon for the first time. I still can't decide which leg of the journey impressed me the most. It is a living memory that no doubt has "improved" with time, but still inspires and propels my imagination.

It was December 21, 1968. As a young college student who had spent a cold and nearly sleepless night on the sand near Cocoa Beach, Florida, I awoke expecting to watch the launch. Instead, I experienced so many more sensations than the merely visual. When the engines ignited, those of us to the south could see only the towering column of exhaust that masked the ascending rocket for more than 20 seconds. Its Sun-bright flame, finally dazzling, was soundless for many seconds more as the roar traveled the distance to us from the distant launch pad. Meanwhile, the rocket raced to outpace its own sound and then the fingers of gravity itself.

When that roar reached us — a rippling rumble, as if the sky were being torn apart — the rocket was already high in the sky and arching east. It left no room in my consciousness for any trivial fact-based knowledge of what actually was happening. The impression displaced all rational thought. I even forgot there were three men on board and where they were headed. The rocket in flight was all my mind could grasp. Finally, the cheering crowds around me broke my concentration and brought me back to Earth.

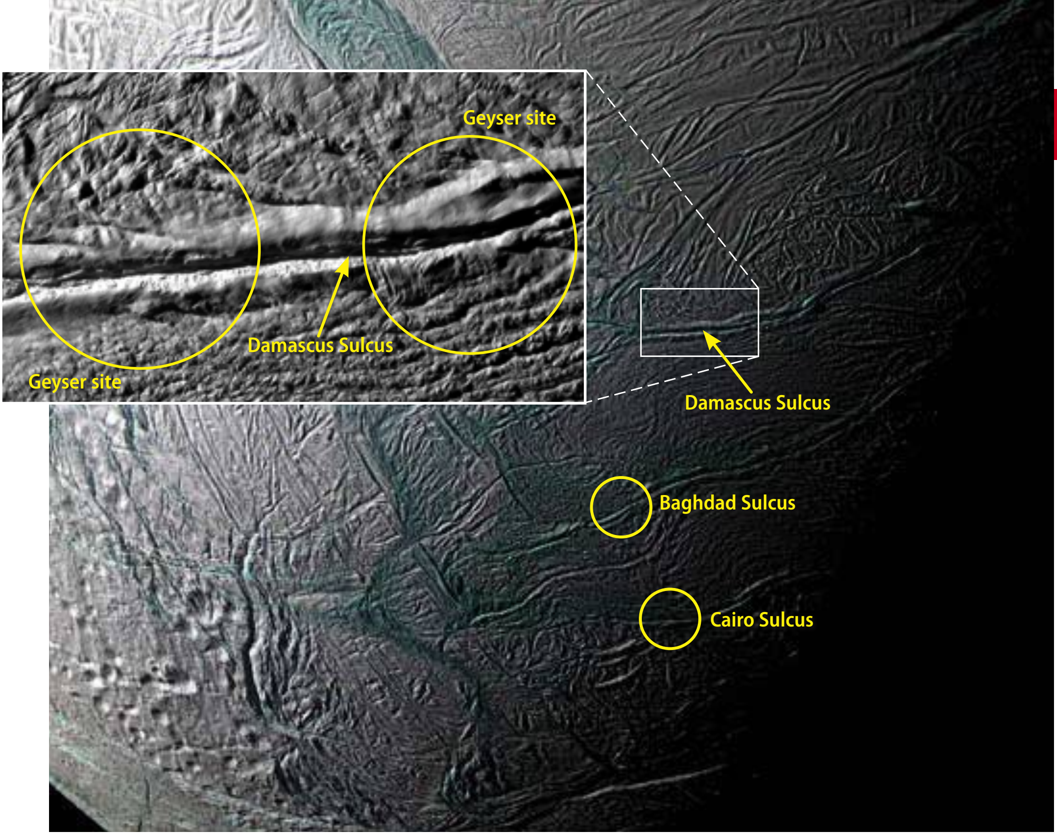
Practical matters pushed the Moon flight out of my thoughts. Grabbing the folded sign I had stashed in my backpack, I walked to the road where westbound traffic was already jammed, to the advantage of my plan. I unfolded the sign: "New York" was all it needed to say.

By Christmas I had reached my home in western New York, and I spent much of my time in front of the television listening to replays of the Apollo 8 crew reports and to news of the successful rocket firing that flung them back toward Earth. I knew that was a dangerous maneuver, but I have no recollection of any anxious moments.

A few days later, with the astronauts home safe, my mother glanced out the kitchen window to see the Moon in the sky. "Men have flown to the Moon," she mused, "but it still looks just the same." She sounded almost disappointed.

Responding to her own almost involuntary amazement that our day-to-day universe was going on just as before, I protested that it wouldn't be like before. "No, not the same," I remember saying. "It'll never again look the same, in the mind of Man."

Naïve and bold words, perhaps, but I'd now argue they and my launch experience were prescient. The historical facts fade, but the stunning reality that these missions occurred has indelibly impressed our culture — so much that we can no longer conceive of a time when Moon flights had not happened. We had become a spacefaring species, and our imaginations were never going to be "brought back down to Earth." I find that most impressive of all. — **JAMES OBERG**



NASA/JPL/SSI

Tiger stripes. The Cassini spacecraft snapped the images for this color mosaic of Enceladus August 11 during a speedy flyby of the saturnian moon. The sites marked by circles represent the locations of four geysers. A close-up of Damascus Sulcus (inset) reveals two geyser sites that jet ice particles into space. Some escape Enceladus' weak gravity and some settle back to the surface, coating the fractures.

Enceladus jets form deep in fractures

The Cassini spacecraft has pinpointed at least four sites on Saturn's moon Enceladus where icy geysers erupt. These spouts, which spew water vapor and icy particles into space, generate the bulk of the material that creates Saturn's tenuous E ring. They originate deep within the "tiger stripe" fractures near the moon's south pole.

Cassini flew within 30 miles (48 kilometers) of the moon's surface August 11. High-resolution images show the fractures reach about 980 feet (299 meters) deep and have V-shaped inner walls. Blocks of ice the size of small houses litter the terrain around the fractures, and fine material covers the outer flanks of several fractures.

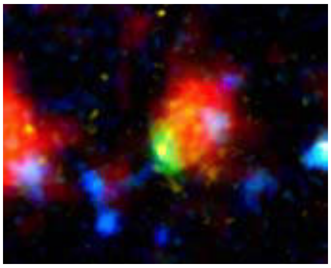
Cassini scientists developed an innovative "skeet shooting" technique to get the sharp pictures. Traveling at 40,000 mph (64,000 km/h), the camera couldn't track surface features. Instead, the imaging team compensated by aiming far ahead of the moon and then spinning the spacecraft and camera rapidly to match Enceladus' motion.

Planetary scientists are now studying the nature of the geysers and their effect on the surrounding terrain. They hope to learn whether reservoirs of liquid water exist beneath the moon's surface. New results should come quickly: Cassini was scheduled to fly past Enceladus twice in October. — **RICHARD TALCOTT**

Brightest starburst galaxy discovered

A galaxy in the early universe, some 12.3 billion light-years from Earth, cranks out as many as 4,000 new stars each year, astronomers reported July 10 in *The Astrophysical Journal Letters*. Nicknamed Baby Boom, the object belongs to a class known as starburst galaxies. Researchers estimate its stellar birth rate is about 400 times that of our Milky Way Galaxy.

Visible-light images from the Hubble Space Telescope and Japan's Subaru Telescope in Mauna Kea, Hawaii, revealed Baby Boom as a distant smudge. Further observations with the Spitzer Space Telescope and Mauna Kea's James Clerk Maxwell Telescope peered through obscuring dust to reveal the galaxy's extraordinary star formation rate. — **M. M.**



NASA/JPL-Caltech/Subaru/STScI

Star maker. The central green and red splotch in this image is the most active star-making galaxy known. It churns out up to 4,000 stars per year.

QUICK TAKES

VIRTUAL NASA HISTORY
NASA celebrated its 50th anniversary August 1, 2008, by releasing a historic virtual tour of its history. Cruise it at www.nasa.gov/50years.

NEW OCEAN MAPPER
The U.S.-French Ocean Surface Topography Mission (OSTM) satellite completed its first map of ocean surface topography less than a month after its June 20 launch.

DOLLARS FOR SCHOLARS
NASA has awarded up to $25,000 for 2 years to 20 undergraduate students and up to $45,000 for 3 years to five graduate students.

A SPACE UPGRADE
Recent renovations prepped MIT's Millstone Hill Radar antenna, the first radar to track objects in space, for many more years of service.

GLAST IS PAST
In August, NASA renamed the recently launched GLAST astrophysical satellite. It's now called the Fermi Gamma-ray Space Telescope, honoring a high-energy physics pioneer.

BYE, BYE VICTORIA
The Mars rover Opportunity climbed out of Victoria Crater August 29 after nearly a year of geological exploration.

SPRINGING TO SPACE
NASA has announced plans to install springs in its future Ares I rocket to dampen potentially dangerous vibrations at launch.

A CHANGE OF POWER
Businessman Enrico Saggese will replace astrophysicist Giovanni Bignami as the head of the Italian Space Agency. Saggese comes from Finmeccanica, Italy's largest aerospace firm.

STARS IN HI-DEF
Recent equipment upgrades made the Beijing Planetarium the world's highest resolution digital dome theater.

LOWELL'S FIRST MILLION
On August 28, Lowell Observatory in Flagstaff, Arizona, commemorated its first million visitors with an all-day celebration.

Slow wind The NASA-European Space Agency Ulysses spacecraft determined that the intensity of the Sun's outflowing "solar wind" is down 20 percent — a 50-year low.

NASA/CXC/UC-Irvine/STScI

Massive fever. The temperature of gas in this galaxy, NGC 4649, revealed that its central black hole contains 3.4 billion times the Sun's mass.

How to take a black hole's temperature

Astronomers have proven the accuracy of a new way to weigh supermassive black holes hiding at the centers of galaxies. Using NASA's Chandra X-ray Observatory, the scientists measured the temperature of gas near the core of the giant elliptical galaxy NGC 4649. The temperature, in turn, revealed the mass of NGC 4649's central black hole to be about 3.4 billion times that of the Sun — a finding consistent with estimates from other methods. The results of the study were accepted for publication in *The Astrophysical Journal*.

Previous techniques deduced a black hole's mass from its gravitational effect on the motions of stars or gas near the galaxy's center. The new technique focuses on the heating effect of a black hole's gravity on nearby gas. Astronomers can measure the gas temperature using NASA's Chandra X-ray Observatory.

As gas spirals toward the black hole, gravity compresses and heats it, causing it to emit X rays. The hotter the peak temperature of the gas near the galaxy's center, the more massive the black hole is.

Two co-authors of the report — Fabrizio Brighenti from the University of Bologna, Italy, and William Mathews from the University of California at Santa Cruz — predicted the new technique a decade ago, but this is the first time astronomers have demonstrated its accuracy. — **D. P.**

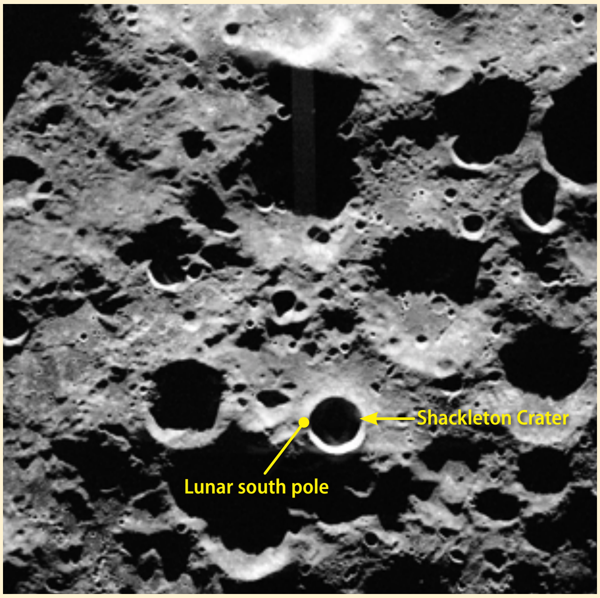
Lunar crater is older and possibly icier

Shackleton Crater at the Moon's south pole is older than previously thought, astronomers reported July 18 in *Geophysical Research Letters*. The crater's greater age could have provided its permanently shadowed floor more time to collect ice, making the site more desirable for a future lunar base.

The crater is about 12 miles (19 kilometers) across. NASA's Lunar Prospector orbiter found evidence of ice at the lunar poles. Astronauts could tap the resource for drinking water and rocket fuel. The crater's rim receives almost continuous sunshine, making it a good location for solar panels.

If Shackleton stores ice, how rich could the resource be? To find out, scientists led by Paul D. Spudis of NASA's Lunar and Planetary Institute in Houston took a close look at images of the lunar pole from Earth-based radar studies and the European Space Agency's SMART-1 probe. The researchers counted the number of meteorite craters near Shackleton to assess the area's age. The more craters, the longer meteorites have bombarded the spot.

Spudis and his colleagues determined that Shackleton Crater could be 3.6 billion years old, making it 2.6 billion years older than the youngest previous estimate. This means the crater was cold enough to collect ice since about 2 billion years ago, when a shift in the Moon's tilt brought Shackleton to its current position at the lunar south pole. — **D. P.**



ESA

Dark past. Shackleton Crater lies almost exactly at the Moon's south pole, a location that leaves much of the crater permanently shadowed. The crater floor may have been storing water for the past 2 billion years.

Courtesy NASA, JPL.

Understand the Forces of the Universe

What forces molded the universe? Are those forces still at work? Will Earth one day be gone? Explorations of questions like these seem available to us every day—provided we have a working understanding of the scientific theories on which they're based.

Dr. Neil deGrasse Tyson, the Frederick P. Rose Director of the Hayden Planetarium at the American Museum of Natural History and Visiting Research Scientist and Lecturer at Princeton University, makes that understanding available to anyone. **My Favorite Universe** is a spirited and intellectually engaging journey through the cosmos and its history, from before the big bang to the likely ways in which Earth, and perhaps the entire universe, might end.

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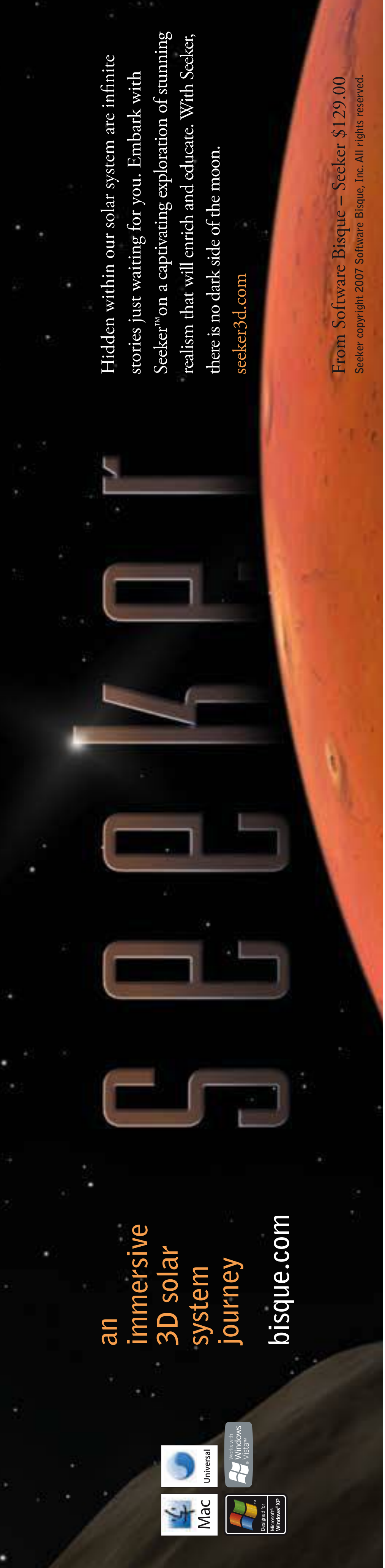
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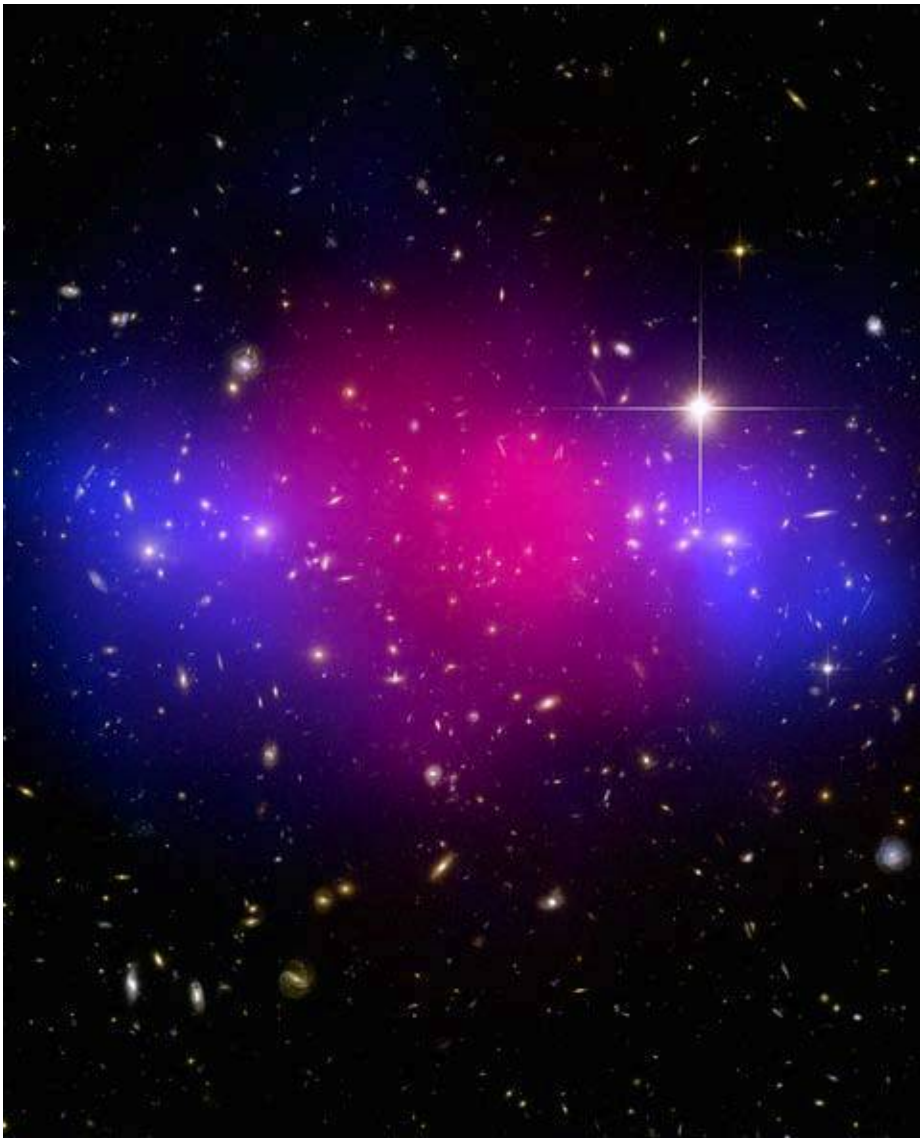


NASA/ESA/CXC/M. Bradac (UC-Santa Barbara)/S. Allen (Stanford University)

Dark clash. In this Hubble/Chandra composite image, blue indicates dark matter and pink charts normal matter. The separation occurred during the collision of two galaxy clusters.

Cluster crash-up reveals dark matter

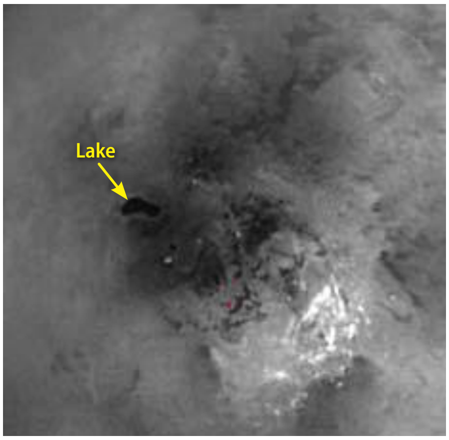
A titanic collision of two galaxy clusters provides new evidence for the existence of dark matter, according to a report slated to appear in *The Astrophysical Journal*. Dark matter, which accounts for most of the universe's mass, doesn't emit light of its own, but astronomers can measure it's gravitational influence on light from more distant objects.

NASA's Hubble Space Telescope and Chandra X-ray Observatory both captured the collision — Hubble using visible light, Chandra in X rays. Combining observations from both instruments enabled astronomers to map the reservoirs of normal and dark matter in the merged object, called MACSJ0025.4–1222.

Hubble imaged the dark matter as two blue areas flanking the cluster's center. Chandra's X-ray detectors charted the normal matter, mostly in the form of hot gas. It appears as a pink region at the cluster's center.

The past collision separated the two types of matter. As hot gas in the two clusters collided and slowed, the dark matter passed right through the impact zone and gathered on opposite sides.

This is only the second cluster collision of its kind imaged by Hubble and Chandra. In a previous target, the Bullet Cluster, dark and normal matter separated in the same pattern as in MACSJ0025.4–1222. — **D. P.**



NASA/JPL/SSI

Ethane, ho! **The dark surface of Ontario Lacus hints at the liquid ethane that fills it. Now spectroscopic observations by the Cassini spacecraft proves the lake's liquid nature.**

Cassini confirms Titan lakes

Scientists long suspected that Saturn's giant moon, Titan, harbored lakes of liquid hydrocarbons — probably methane and ethane. Now they have proof. Observations made by the Cassini spacecraft in December 2007 revealed the spectral fingerprint of liquid ethane, removing any lingering doubt. The discovery makes Titan the second object known, after Earth, to have liquids on its surface.

"This is the first observation that really pins down that Titan has a surface lake filled with liquid," says Robert H. Brown of the University of Arizona in Tucson, team leader of Cassini's Visual and Infrared Mapping Spectrometer (VIMS). The researchers reported their results July 31 in *Nature*.

The VIMS team viewed Ontario Lacus, a lake in Titan's south polar region slightly bigger than North America's Lake Ontario. Images from previous flybys showed Ontario Lacus as a dark, elongated region, but no one knew if it was filled with liquid or might simply be a dry lakebed.

To detect the liquid ethane, the VIMS team used a technique that removes interference from the thick hydrocarbon smog in Titan's atmosphere. The observations also show that the lake may be evaporating. A dark "beach," where the black lake merges with the bright shoreline, rings Ontario Lacus.

During the next few years, the VIMS researchers plan to start observing the large number of suspected lakes near Titan's north pole. The Sun has just started to rise over this region after 14 years of darkness. — **R. T.**

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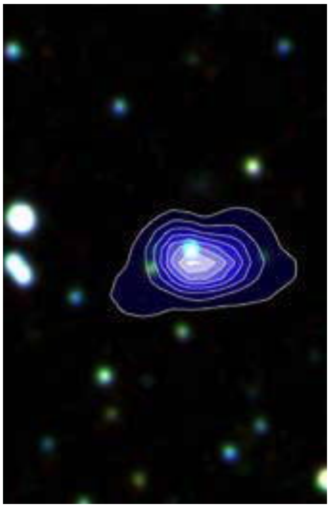
Bar scene A galaxy census has discovered that barred-spiral galaxies were far less common 7 billion years ago than now. Galaxies may develop the bars as they mature.


ESA/XMM-Newton/EPIC/SuperCOSMOS Sky Surveys

Almost missed you. In this image of the nova V598 Puppis (central white dot), the blue within the contour rings marks the star's lingering X-ray glow.

X-ray satellite spots nearly overlooked nova

If a star went nova and nobody was there to see it, did it really happen? For an obscure star in the constellation Puppis, astronomers can now say "Yes." On June 5, 2007, the star brightened dramatically in visible wavelengths — enough to be seen by the naked eye. But nobody reported the nova, caused by nuclear explosions on the distant star's surface.

A few months later, however, the XMM Newton satellite caught the still-detectible X-ray glow from the event, astronomers reported in May in *Astronomy and Astrophysics*. The almost-overlooked nova is now known as V598 Puppis.

Astronomers discovered the stellar outburst by chance October 9, 2007. While changing targets, XMM Newton's field of view passed over a bright but previously undocumented X-ray source.

The scientists sent an astronomical telegram to alert other observers. Further investigation showed that a robotic telescope survey on Earth had caught the nova at the time of its brightening 4 months earlier. — **D. P.**

High-tech skin keeps satellites cool

Engineers have developed a heat-regulating spacecraft skin that could make it easier to operate fleets of "microsatellites," each no larger than a birthday cake and weighing around 50 pounds (23 kilograms). Researcher Prasanna Chandrasekhar of Ashwin-Ushas Corporation in Lakewood, New Jersey, described the new material August 19 at the national meeting of the American Chemical Society in Philadelphia.

Lofting a satellite is costly — around $5,000 per pound right now. Microsatellites or smaller "nanosatellites" weighing around 10 pounds (4.5 kg) could conduct research at a lower cost. There's just one problem: Microsatellites are too small to carry the bulky conventional refrigeration hardware engineers typically use to regulate temperature swings in space.

Satellites orbiting Earth alternate between the Sun's naked glare and the chilled-out shadow zone behind the planet. "It may sound very trivial, but controlling the temperature of a spacecraft is absolutely crucial," Chandrasekhar says. "Currently, there is no way to do it for very small spacecraft."

Chandrasekhar's prototype heat-regulating skin would cover the satellite's outer surface. It consists of an electrically conducting material sandwiched by two thin sheets of gold-coated polymer. The coating reflects most visible and ultraviolet radiation. Applying a small voltage across the sandwich allows heat to pass through it out into space. Ashwin-Ushas is developing the heat-regulating skin with NASA. — **D. P.**

BRIEFCASE

SDSS III begins

In July, the Sloan Digital Sky Survey (SDSS) completed its second phase, SDSS II. In 8 years, the consecutive SDSS I and SDSS II programs completed the largest three-dimensional maps of the universe, captured more than 25 percent of the sky, and measured distances to nearly a million galaxies and 100,000 quasars. SDSS III will last for 6 years. — M. M.

Hubble's rising odometer

The Hubble Space Telescope completed its 100,000th orbit around Earth August 11. Since the telescope's 1990 launch, it has traveled about 2.72 billion miles (4.38 billion kilometers). To commemorate the milestone, NASA released a dazzling portrait of star birth near the star cluster NGC 2074. This region, about 170,000 light-years from Earth, is one of the most active star-forming regions in our local group of galaxies. — M. M.

Rocket pad for rent

On August 7, Air Force Space Command announced a proposal to allow Florida to operate Cape Canaveral Air Force Station's Space Launch Complex (SLC) 36 as a commercial space launch facility. If approved, the proposal will grant Florida access to the property for an initial 5 years.

NASA operated SLC 36 until 1989, when the Air Force and General Dynamics began using it to launch military and civilian missions. SLC 36 saw its last launch in 2004. — M. M.

25 years ago in *Astronomy*

December 1983

In the December 1983 *Astronomy*, Stephanie Mood asked if Jupiter's moon Europa could support life. In "Life on Europa?" Mood argued that there could be a global ocean tens of miles deep under the moon's icy surface. "This scenario may never prove true, but we should always remember life is ingenious," Mood wrote. "It survives under alien conditions even at our own doorsteps. If Europa's organisms existed, they would float or move slowly through a cold dark liquid."

Scientists have no evidence of life on Europa yet, but the search continues elsewhere. In May, NASA's Phoenix Lander touched down in the martian arctic to analyze the soil and its potential to host life. Planetary scientists still hope to eventually explore Europa's hypothesized ocean.

10 years ago in *Astronomy*

December 1998

In *Astronomy's* December 1998 issue, Andrew Lawler's "Onward into space" discussed the International Space Station (ISS). At the time, astronomers were not convinced the planned ISS would prove useful to science. "They complain there is little evidence that the space station will benefit life and material sciences," Lawler wrote.

Today, the ISS orbits Earth at an altitude of about 217 miles (350 kilometers), available to conduct experiments that require the unusual conditions of outer space. An effort is underway to establish the facility as a national laboratory. By 2010, four new research modules are scheduled to arrive at the ISS. — **M. M.**

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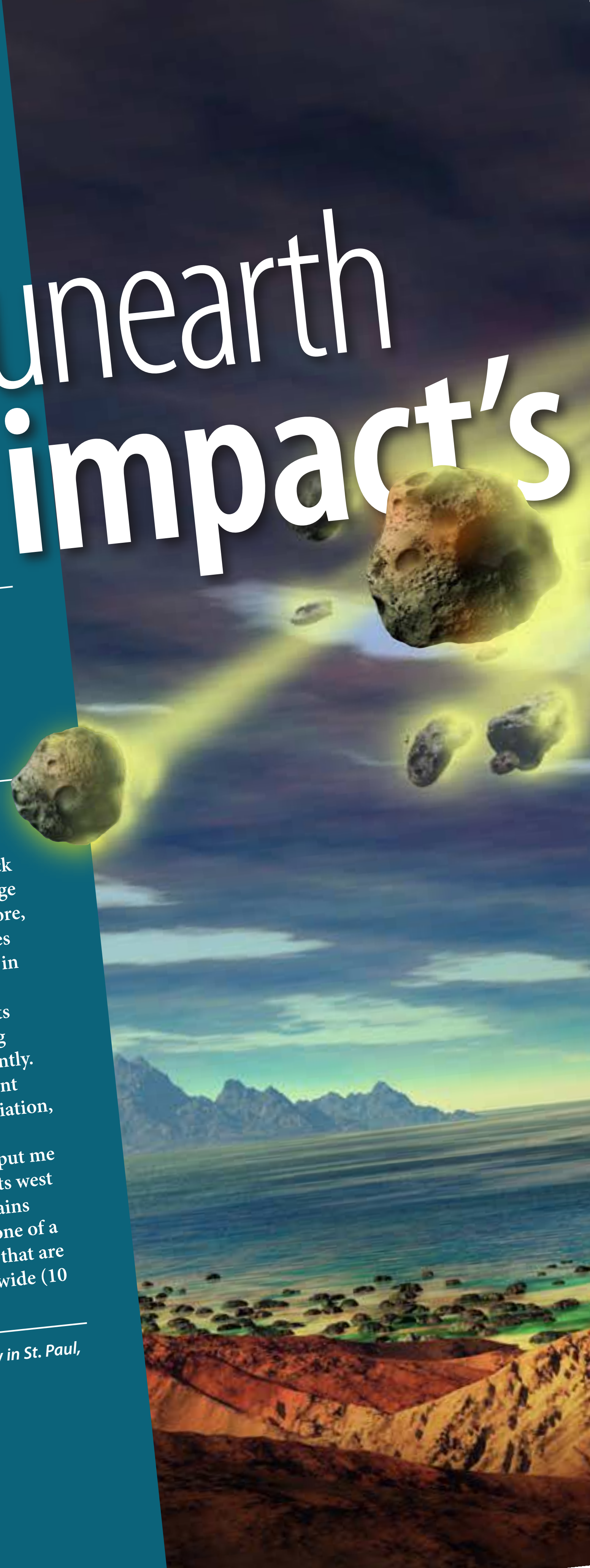
Scientists unearth ancient impact's

A giant meteorite struck Earth 1.8 billion years ago, creating Sudbury Basin. What does this event tell us about early Earth? **by Mark Jirsa**



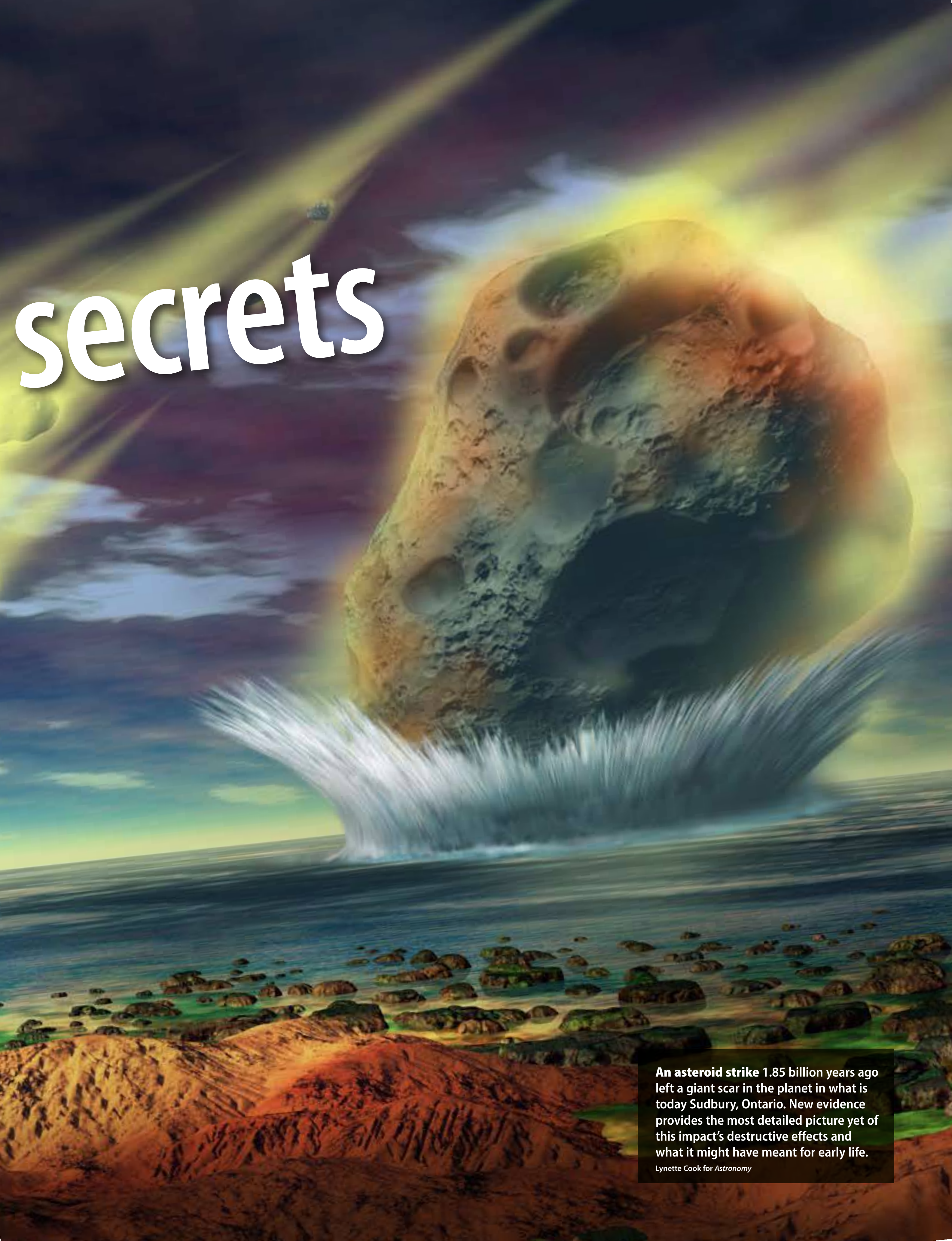
About 1.85 billion years ago, a massive object from space smashed into Earth at what is now Sudbury, Ontario. Back then, a shallow sea covered the surface. A mountain range poked above the horizon to the south. Along the seashore, dense colonies of cyanobacteria grew in stumpy masses called stromatolites. The impact blew a gaping crater in the seafloor about 160 miles across.

We can roughly estimate the crater's original size from its highly eroded remnant, the Sudbury Basin. As for anything more detailed than that, nobody could say until fairly recently. Earth's dynamic surface gradually erases evidence of ancient impacts, whether through erosion, burial, volcanism, glaciation, or the obscuring cover of plants.

In 2007, a combination of luck and a major forest fire put me face to face with a strange layer cake of geological deposits west of Gunflint Lake in Minnesota. One of the deposits contains debris blasted 470 miles from the Sudbury impact. It is one of a dozen deposits scattered around the Great Lakes region that are revealing new clues to what happened the day a 6-mile-wide (10 km) space rock smashed into the tranquil sea.

Mark Jirsa *is a geologist with the Minnesota Geological Survey in St. Paul, Minnesota. This is his first article for* Astronomy.

secrets



An asteroid strike 1.85 billion years ago left a giant scar in the planet in what is today Sudbury, Ontario. New evidence provides the most detailed picture yet of this impact's destructive effects and what it might have meant for early life. Lynette Cook for *Astronomy*

Thunder Bay
Isle Royale
Lake Superior

The Ham Lake fire raged in northern Minnesota in May 2007. NASA's Terra satellite captured this image of the smoke plume drifting east into Ontario. NASA

Fiery field trip

My involvement with the Sudbury impact started near the Gunflint Trail, originally a footpath connecting inland lakes to Lake Superior. The trail is now a 57-mile (92 km) paved road that runs from Grand Marais, Minnesota, to Seagull Lake near the U.S.-Canada border.

In May 2007, I helped to plan and lead a geological field trip as part of an annual meeting of a professional society I belong to, the Institute on Lake Superior Geology. The planned trip would have brought our group to rock outcrops along several miles at the very northern end of the Gunflint Trail.

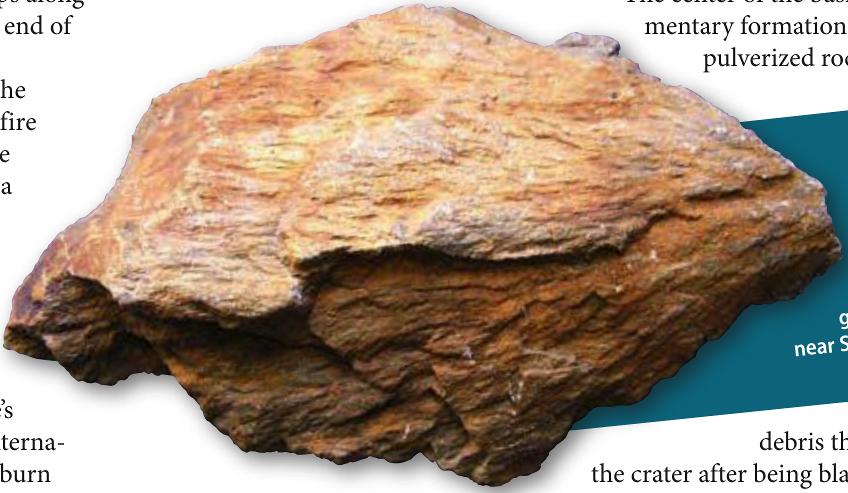
But in the days leading up to the conference, the Ham Lake forest fire erupted. It quickly spread into the largest fire in northern Minnesota since 1894. The conflagration hit the upper Gunflint Trail hard, burning more than 40,000 acres. The fire claimed some 200 structures.

To make sure our field trip didn't end up being one of the fire's casualties, I decided to scout an alternative destination at the edge of the burn and west of Gunflint Lake. As I was walking along the boundary between burned and unburned woods, the fire raged just over the hills to the north, and I could clearly see smoke on the horizon.

Most of the rocks in this area are dark in color. But as I crested a low ridge, I noticed some unusually light-colored rocks that formed the next ridge to the north. As I approached the northern ridge, I recognized that it contained iron-rich rock common in the area. This rock, though, was broken into large fragments and cemented together into a "breccia."

Then it got stranger still. I noticed a portion of the deposit containing green and brown rock spheres, about ½ to ¾ inch (13 to 19 millimeters) across. I had no clue what they could be.

It was getting dark, and I had to prepare for the meeting. So I gathered up a few fist-sized samples of the breccia and spheres and began to drive the 40 minutes back to the Lutsen Resort on Lake Superior, where the conference was being held. I didn't know it at that moment, but the odd outcrop near Gunflint Lake held valuable new clues to one of the most violent events in Earth's history — the Sudbury meteorite impact.



Shock waves from the Sudbury impact created sandstone "shatter cones" like this one as the energy passed through the ground. This one formed near Sudbury, Ontario. Mark Jirsa

Clues to a catastrophe

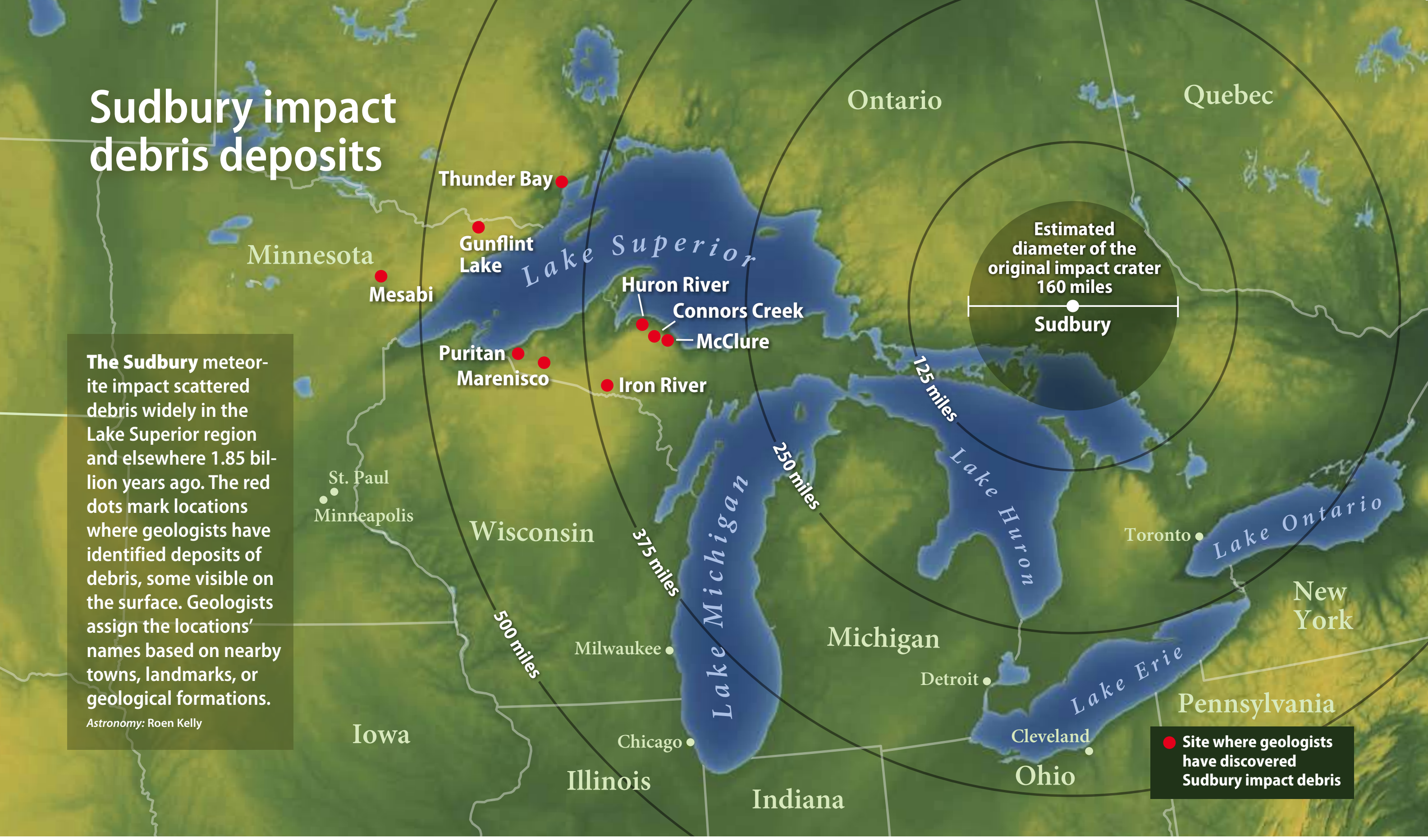
Sudbury Basin marks the remnant of a catastrophic extraterrestrial impact. The shock liberated more than 6,500 cubic miles (27,000 cubic km) of debris, blanketing nearly 1 million square miles (2.6 million square km).

The Sudbury impact is one of 174 scientifically verified impact structures on Earth. The largest is the Vredefort structure in South Africa, which formed 2 billion years ago. The oldest is the Suarjarvi impact structure in Russia, dating back 2.4 billion years. By contrast, the impact most widely known to the public — the Chicxulub event associated with the dinosaurs' demise — is relatively young (65 million years old). Its crater was somewhat smaller than Sudbury's: 110 miles in diameter.

Today's Sudbury Basin is an oval depression in the land, measuring roughly 20 by 40 miles (32 by 64 km). Erosion carved the basin from rock layers associated with the impact event. An erosion-resistant rock formation, called the Sudbury intrusion, defines the basin's outer rim. This appears to have solidified from rock melted by the tremendous energy of the impact. Geological dating tells us the rock solidified 1.85 billion years ago, giving us a "hard" date for the meteorite strike.

The center of the basin contains sedimentary formations composed of pulverized rock and other debris that fell back into the crater after being blasted into the air by the impact. As crustal plates collided 900 million years ago, the resulting tectonic strain stretched the remnant crater into an oval bowl.

The most compelling evidence for the Sudbury impact is the presence of deformation patterns in nearby sandstone called shatter cones. They form when intense shock waves — the kind that



Sudbury impact debris deposits

The Sudbury meteorite impact scattered debris widely in the Lake Superior region and elsewhere 1.85 billion years ago. The red dots mark locations where geologists have identified deposits of debris, some visible on the surface. Geologists assign the locations' names based on nearby towns, landmarks, or geological formations. *Astronomy:* Roen Kelly

● Site where geologists have discovered Sudbury impact debris

Ontario
Quebec
Thunder Bay
Gunflint Lake
Minnesota
Mesabi
Lake Superior
Huron River
Connors Creek
McClure
Puritan
Marenisco
Iron River
Estimated diameter of the original impact crater 160 miles
Sudbury
125 miles
250 miles
375 miles
500 miles
St. Paul
Minneapolis
Wisconsin
Lake Michigan
Lake Huron
Toronto
Lake Ontario
New York
Milwaukee
Michigan
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emanate from a large meteorite impact — move through the subsurface.

"Ejecta" deposits are another important source of evidence for impacts. They contain debris propelled hundreds or even thousands of miles before being incorporated into sediments, such as sand and mud. They sometimes contain telltale clues linking them to an impact. One example is "shocked quartz" mineral grains deformed in a distinctive manner as the tremendous energy of an impact rips through the ground.

Ejecta sometimes contain accretionary lapilli, a mix of tiny rock fragments, ash, and solidified droplets of molten rock. The lapilli harden in impact-generated mushroom clouds and then rain down onto the surface. Later, they turn up in sedimentary rock deposits as small rock spheres — just like the ones I had found in the deposit near Gunflint Lake.

Eureka — it's an impact!

A few minutes into my drive back to the resort, it came to me like a flash — I had seen those rock spheres before! It happened 2 years earlier, at a geology meeting in Thunder Bay, Ontario. A colleague of mine, William Addison, had showed them to me in a rock sample he found near Thunder Bay, on Superior's northwest shore. He suspected the spheres were part of the ejecta from the Sudbury meteorite impact.

Addison is a high school science teacher from Thunder Bay. He and a fellow instructor, Gregory Brumpton, had found the ejecta deposit after a 15-year search. These dedicated amateurs published their work in *Geology* in 2005.

William Cannon of the United States Geological Survey in Reston, Virginia, joined the search for Sudbury debris. He has discovered five debris deposits in the Lake Superior region, all of them lying near the top of various formations of iron-rich rock dating to just before the Sudbury impact.

As this flashed into my recollection, I slammed on the brakes, pulled over, and dug out a geologic map. I studied the map for a moment and determined that the outcrops I had just seen were also near the top of iron-rich deposits — the Gunflint Iron Formation! Had I found another example of Sudbury debris?

When I arrived at the resort, many of my associates, both Canadian and American, were mingling in the parking lot. After the obligatory greetings, I pulled the samples out and handed them to Bill Cannon. He usually doesn't get visibly excited, so his reaction was out of character. "You've found it!" he exclaimed.

A devastating blast

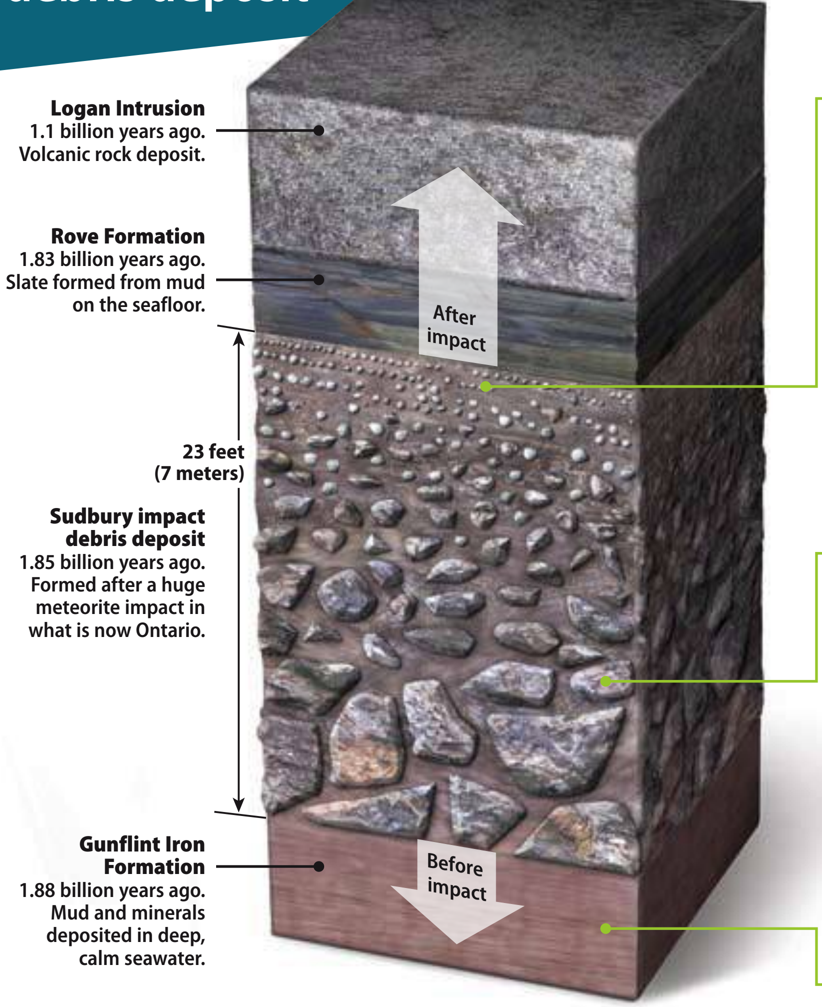
The impact deposits are revealing important new details of what may have happened 1.85 billion years ago. I say "may" because the picture is far from completely clear yet. But the recent finds have given us new possibilities to consider.

What would it have been like to stroll among the stromatolites at the moment of impact? Whatever the experience, it was a brief thrill.

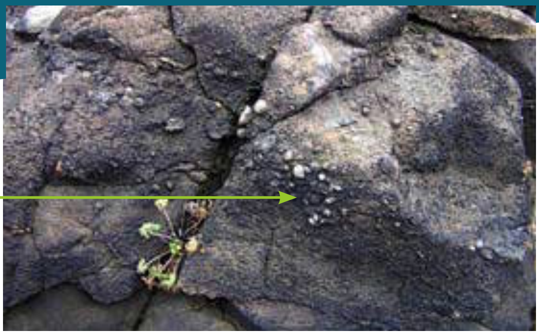
At impact, the meteorite blasted a vast "water hole" into the sea and then, a moment later, smashed into the underlying crust. An observer's first — and last — sensation would be heat from the flash of thermal radiation unleashed by the impact. The heat blast would sear the stromatolites to cinders as violent earthquakes rocked the shoreline.

Within seconds, a hot plume of vapor, ash, rock fragments, and droplets of molten stone rose explosively through the atmosphere and began to spread outward. Even 470 miles away at what is now Gunflint Lake, the impact's blast would have been devastating.

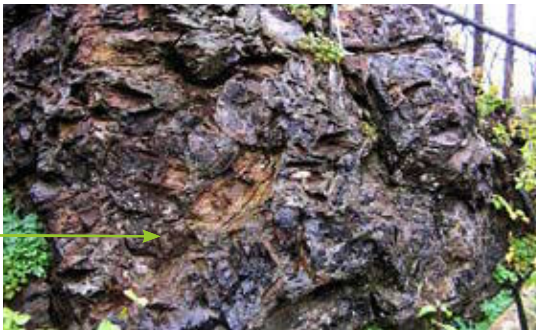
The Gunflint Lake debris deposit


Logan Intrusion
1.1 billion years ago.
Volcanic rock deposit.
Rove Formation
1.83 billion years ago.
Slate formed from mud on the seafloor.
After impact
23 feet (7 meters)
Sudbury impact debris deposit
1.85 billion years ago.
Formed after a huge meteorite impact in what is now Ontario.
Gunflint Iron Formation
1.88 billion years ago.
Mud and minerals deposited in deep, calm seawater.
Before impact

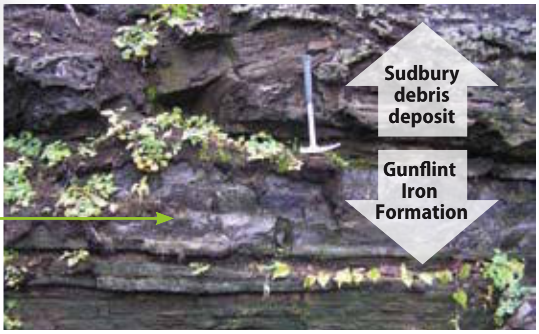
The Gunflint Lake deposit contains various types of debris blasted hundreds of miles from the Sudbury meteorite impact 1.85 billion years ago. The base of the deposit holds the coarsest fragments of rock debris. With height, the debris sorts by size, with the smallest and lightest chunks toward the top. Capping the deposit is a mix of tiny rock fragments and spherical "lapilli." The spheres solidified from fine debris particles. *Astronomy*: Roen Kelly



The top of the deposit contains rock spheres intermixed with tiny rock fragments. Mark Jirsa



The base of the deposit contains large and medium-sized rock fragments cemented together into a coarse "breccia." Mark Jirsa


Sudbury debris deposit
Gunflint Iron Formation

The Sudbury impact deposit lies on top of an older rock layer called the Gunflint Iron Formation. Mark Jirsa

In the turbulent cloud of ejecta, some of the ash and vapor coalesced into spherical stones (accretionary lapilli), similar to the way water forms hailstones during violent thunderstorms. The hail of stones rained on the landscape. Millions of them sank to the sea bottom. Mud encased the debris over time, and they hardened into sedimentary rock — preserving a record of the event for geologists to discover 1.85 billion years later.

New clues

The Sudbury impact deposits open a window into a brief moment in geological time and a catastrophic natural disaster. By reading the rocks, we learn how the deposits may have formed. One thing we see in the rock record is possible signs of the giant sea waves (a tsunami) that raced outward from the ocean impact site like the ripples set in motion by a stone tossed into a pond.

By the time the tsunami hit, the seabed and seashore would have been a tumble of fragmented rock and ash. Tsunami waves might have torn across the area forcefully enough to disrupt the submarine debris, mixing it into a jumbled mess that gradually settled and hardened into sedimentary rock.

The slice of geological time exposed near Gunflint Lake is a tightly cemented mixture of black, green, and brown colored fragments of rock from the Gunflint Iron Formation. Those fragments may represent portions of the seafloor torn apart by shock waves and then later swirled into a tumble by tsunami waves. Small green spheres of accretionary lapilli and tiny rock fragments — possibly fallout from the impact — wedge in between the large fragments.

The deposit I found near Gunflint Lake is a layer cake 23 feet (7 meters) thick that tilts gently to the south. Like the deposits at Thunder Bay, it is sandwiched between the older Gunflint Iron Formation below (1.88 billion years old) and the younger Rove Formation above (1.83 billion years old).

Most of the deposit consists of pieces of fragmented rock cemented together — the breccia. The largest fragments are about 10 feet long (3 meters); the smallest are mere grains. The fragments' orientations are chaotic and nearly random, with some standing on end. What are these rocks trying to tell us?

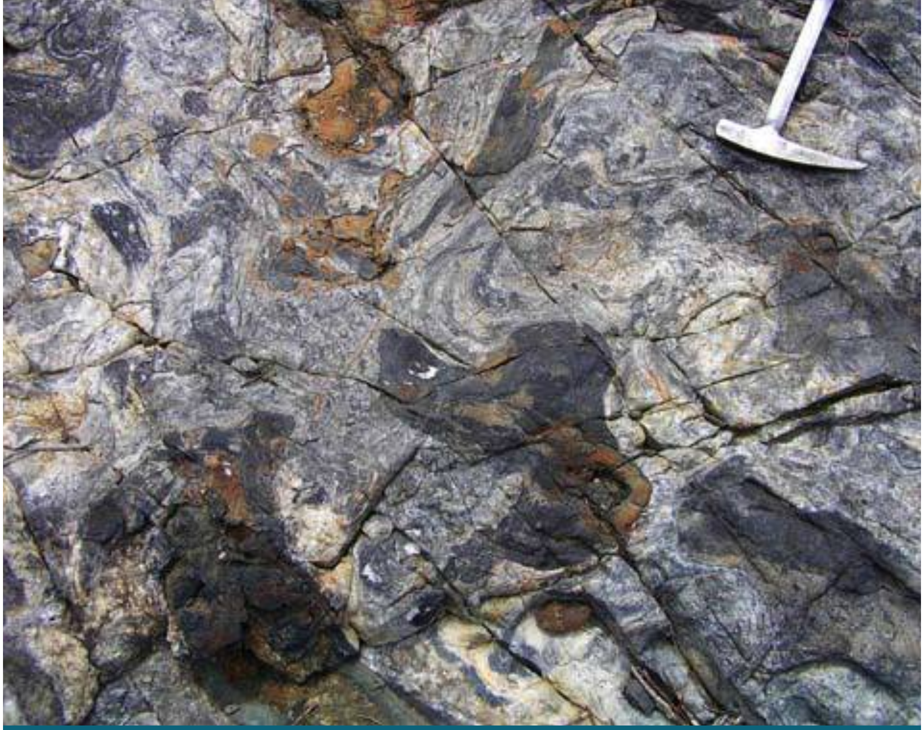
The organization of fragments within the breccia at Gunflint Lake records a sequence of geologic events. For example, the largest fragments occur near the bottom of the layer, and smaller fragments occur near the top. This suggests deposition by a single, high-energy event that waned quickly, allowing the material to sort itself by weight — heaviest at the bottom, lightest at the top.

Recent fieldwork on the deposit suggests some of the fragments were initially encased in mud that gradually solidified around it. One way to interpret this is that earthquakes triggered a massive underwater landslide of debris down a muddy submarine slope. Today we may be looking at its compacted remains.

A layer of spherical lapilli and small rock fragments caps the breccia deposit in many locations. At this point, it's unclear what this layer represents. It could have formed as late fallout from the ejecta cloud, or was deposited by the backwash of a large tsunami.

Global effects?

The Sudbury impact was such a massively energetic event, one cannot help but wonder about its global ramifications. Did it cause widespread ecological disruption and mass extinction, as some researchers believe the Chicxulub impact did during the dinosaur age?



The swirling patterns in this rock trace the fossilized remains of bacterial colonies, called stromatolites. The effects of the Sudbury impact might have caused these organisms to go into global decline. Mark Jirsa

The jumbled rock fragments in this outcrop may preserve the remains of an underwater landslide triggered by seismic shaking from the Sudbury impact. Mark Jirsa

At the time of the impact, the only life-forms that existed were microscopic cyanobacteria. The fossilized remains of their colonies, called stromatolites, are common in the Gunflint Iron Formation.

Being photosynthetic organisms, the cyanobacteria produced "free oxygen," releasing it into the ocean and atmosphere. In fact, researchers believe a global cyanobacterial boom just before the Sudbury impact infused Earth's environment with oxygen, making new forms of life possible. Oxygenation also caused dissolved iron and silica to precipitate out of the previously anoxic seawater and form massive banded iron deposits on the seafloor. We have mined these formations extensively for iron ore.

Banded iron deposits stopped forming around the same time as the Sudbury impact. Is there a connection? Could the impact have caused the cyanobacteria to go extinct, thereby ending the favorable conditions for iron deposition? It's a good question, but we don't have the answer yet.

Work on the ejecta deposits is underway, but still in its infancy. There's a lot of work that needs to be done in the field to see what the Gunflint Lake deposit tells us that other sites don't. It lies in a different geological setting: It's a little farther away from the impact and the rocks are altered differently. It may reveal some secrets about the impact that other discoveries haven't — or that's what we hope will happen.

The Sudbury impact deposits have given us access to one of the largest, best exposed, and oldest impact debris blankets ever studied. It holds great promise for answering questions about the nature of the early atmosphere, the dynamics of the impact event itself, and the composition of the meteorite.

Ironically, Lake Superior geologists have stared right at debris from the Sudbury impact for nearly a century with little idea of its true nature. Generations of geologic mappers have gathered at the historic Gunflint Lodge on the south shore of Gunflint Lake after long days of fieldwork. The lodge's prominent fireplace was constructed in 1927 from strange looking cobbles that the owner ferried by the boatload across Gunflint Lake. The geologists undoubtedly pondered the origin of these unusual rocks in the fireplace. But it took a forest fire to finally reveal the rocks' secret.

The fireplace stones are a postcard from an ancient catastrophe that rocked the Lake Superior region nearly 2 billion years ago, one that might have altered the path of evolution. Who knows what more the rocks have to teach us?

How the Sun will die

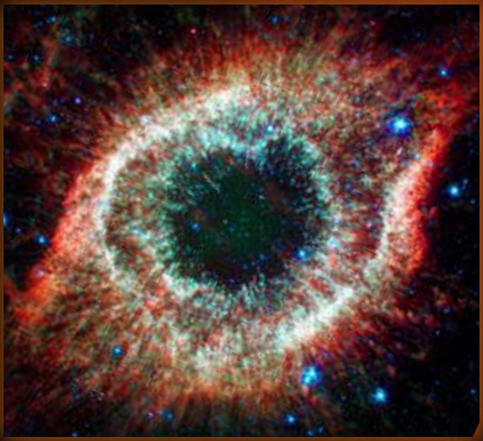
When Sun-like stars exhaust their fuel, they cast off shells of gas, creating colorful fireworks.

by Bruce Balick

Our Sun has lived half its life. Five billion years from now, its inner workings will trigger a transformation. For a brief span, distant observers will not see a star, but a colorful, expanding cloud of gas called a planetary nebula.

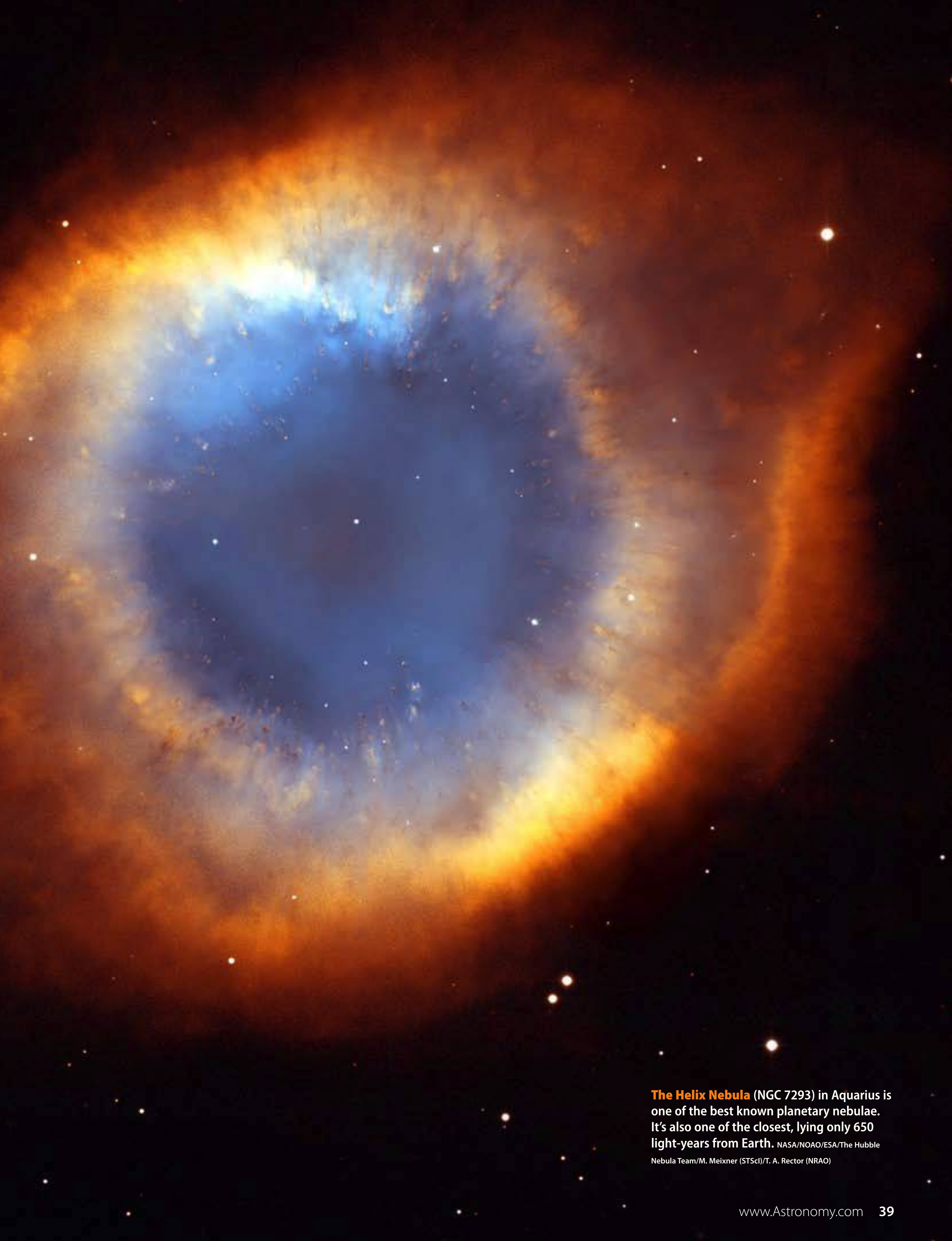
Astronomers pay close attention to planetary nebulae, and these objects have gotten more popular since the mid-1990s, when the Hubble Space Telescope began delivering spectacular photographs of them. In fact, a new planetary nebula has probably flared to life somewhere in the Milky Way since Hubble went into service. The object may be too far, too small, or too faint to detect, but it's out there waiting to return our gaze.

Despite the efforts of astronomers using Hubble and many other instruments that have probed planetary nebulae in every wavelength, there remain important aspects of these enigmatic objects we don't understand.

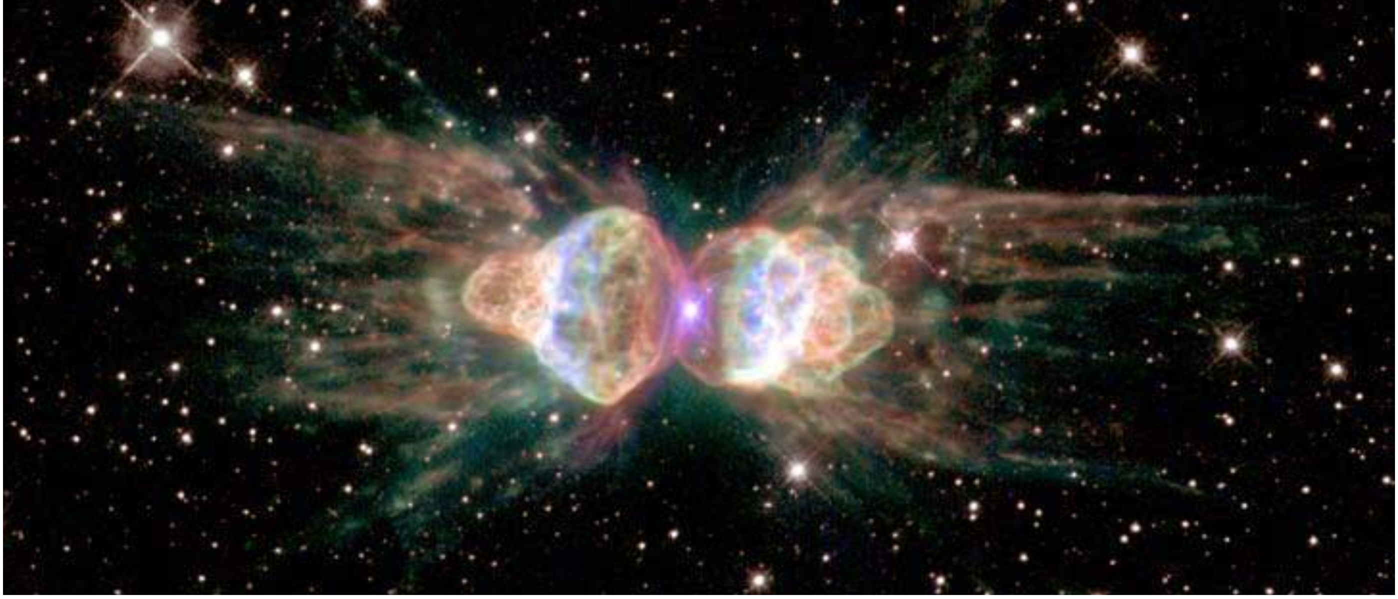


This infrared view of the Helix Nebula from NASA's Spitzer Space Telescope shows features called "cometary knots" with blue-green heads. The knots glow brightly — because of shock fronts or ultraviolet radiation — at wavelengths between 3.2 and 4.5 microns, to which astronomers assigned the colors blue and green, respectively.

NASA/JPL-Caltech/J. Hora (Harvard-Smithsonian CfA)



The Helix Nebula (NGC 7293) in Aquarius is one of the best known planetary nebulae. It's also one of the closest, lying only 650 light-years from Earth. NASA/NOAO/ESA/The Hubble Nebula Team/M. Meixner (STScI)/T. A. Rector (NRAO)



The Ant Nebula (Menzel 3) resembles a garden-variety ant. This Hubble image reveals the ant's body as a pair of fiery lobes protruding from a dying Sun-like star. The Ant Nebula lies in the southern constellation Norma approximately 3,000 light-years away. NASA/ESA/The Hubble Heritage Team (STScI/AURA)

The majority rules

The story of a planetary nebula starts at the end of a star's red giant phase. That's when the star's core finally dies. It becomes a dense, Earth-sized lump of carbon containing about 50 percent of the Sun's original mass. The core has no way to replenish its heat, so it cools like an ember in a fireplace.

Some life remains in the layers outside the core, however. Gravity has compressed shells of fresh hydrogen and helium to their thermonuclear fusion points. They burn furiously, but only briefly. For example, the Sun will be about 30 times brighter than now when it enters the red giant stage. At the most luminous stage of its evolution, however, it will be 150 times larger and 2,100 times more luminous than it is now.

Within stars that will become planetary nebulae, carbon is the ultimate fusion byproduct. Such a star's atmospheric carbon settles down and adds its mass to the inert carbon core. The remaining fuel is too far from the core, so not enough mass remains above it to compress it to its fusion point. Instead, the last spasmodic fits of helium "burning" — a colloquial term substituted for "fusion" by astronomers — fling these outer layers into space, resulting in a planetary nebula a thousand years later. Each of the spasmodic "sneezes" produces a new bubble of gas flowing outward at about 36,000 mph (58,000 km/h). Astronomers can see these bubbles as concentric rings of luminous gas in many Hubble images of planetary nebulae.

Bruce Balick *is Chairman of the Department of Astronomy at the University of Washington, Seattle. He serves on the design team for WFPC 3.*

This cosmic jellyfish actually is planetary nebula OH231.8+4.2, sometimes called the Rotten Egg Nebula. Shown in blue is light from hydrogen and ionized nitrogen arising from supersonic shocks where the gas stream collides with surrounding material. This image showed, for the first time, these complex gas structures predicted by theory. ESA/Valentin Bujarrabal (Observatorio Astronomico Nacional, Spain)

The star's final helium flash is a doozy. Instead of another bubble, we get a dense and highly organized spray of gas and fresh dust particles. This event creates the planetary nebula's shape — that is, its complex inner structure and organization. The "superwind" is too organized and symmetric to be the chaotic remnant of an explosion. Rather, there's method — or perhaps a few methods — in the mad out-rush of material.

In many planetary nebulae, the dark dust lane and the bright lobes seen in images along their major axes form in the final helium flash. This material cools as it expands. Based on observations, astronomers surmise dust particles quickly condense at the base of the outflow just before the gas disperses.

New dust makes up about 1 percent of the mass ejected into the interstellar medium. This enriches the surrounding area with carbon- and silicate-rich particles along with a variety of carbon-based molecules. The dust particles are small (0.001 millimeter or so) and reflect light from the nearby dying star.

The newly born preplanetary nebulae (sometimes called protoplanetary nebulae) are small and far away on average. Because they appear tiny, Hubble is the observing tool of choice.

Only the most elite of all stars — those whose mass puts them in the upper 1 percent — become supernovae. The rest settle for "15 minutes of fame" before they fade away, and we see the results as planetary nebulae. That time span — when the star ejects and ionizes its outer layers in a final fiery, smoky breath — is what attracts astronomers' attention.

Planetary nebulae ultimately expand and disperse into the ocean of galactic gas known as the interstellar medium. All that remains are ever-cooling white dwarfs — nature's burnt cherry pits — too faint to see after a billion years and too numerous to name.

Revealing a planetary

It takes about a thousand years for a new planetary nebula to become visible. Its gas has to expand to a size we can detect, and the star at its center must shed its cool outer layers and reach a temperature of about 30,000 kelvins (K).

Before this happens, the nascent planetary nebula shines only because its newly formed dust particles happen to reflect starlight in our direction. Indeed, the dust may hide the visible light entirely until the nebula expands for a while and light finds pathways out of the opaque cocoon.

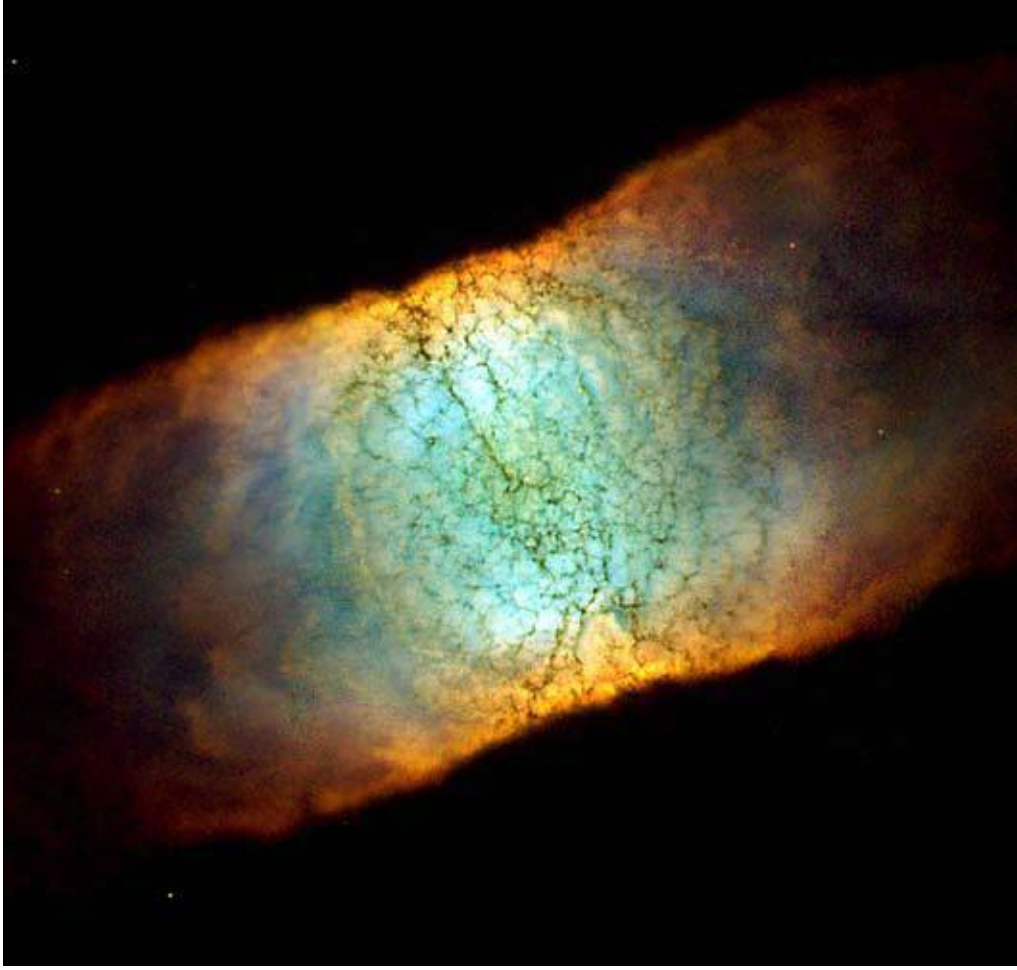
At 30,000 K, ultraviolet photons start to strip electrons from neutral atoms. This ionizes the gas, rendering the planetary nebula visible. The object's spectrum shows lines of hydrogen, helium, and other elements. Using filters that isolate these emissions, Hubble and other telescopes can take the spectacular color images we've grown accustomed to.

No chain is stronger than its weakest link, and no theory of stellar evolution can be complete without understanding the origin of the shapes of planetary nebulae. It's a thrill for an observer like me to get imaging time on Hubble. However, there's a sobering — and, for the really spectacular nebulae, gut-wrenching — realization that we have not yet explained the structure of these amazing objects.

From a scientific viewpoint, images of preplanetary nebulae pose a problem. All known stellar wind acceleration mechanisms convert light energy from the star into outward motions of dust particles. Just like the Sun shining on a comet's tail, light pushes on the dust particles and forces them to flow outward. If the star is round, then the outflows also should look round. Almost none of the preplanetary nebulae behave this way, however.

A planetary nebula "gets its certificate" when the central star becomes hot enough to ionize the preplanetary nebula.

Spanish radio astronomers uncovered a second problem in 2001. They measured the Doppler shifts from carbon monoxide (CO) emissions (CO is always a bountiful molecule in cool, dusty gas) and found the momentum of the outflowing gas is more than 10,000 times larger than light-pressure based acceleration mechanisms had predicted.



The Retina Nebula (IC 4406) exhibits a high degree of symmetry; the left and right halves are nearly mirror images of each other. Gas and dust form a vast doughnut of material streaming outward from the dying star. One perplexing feature of IC 4406 is the irregular lattice of dark lanes that crisscross the nebula's center. We see them in silhouette because their density is 1,000 times greater than the rest of the nebula. NASA/The Hubble Heritage Team (STScI/AURA)/C. R. O'Dell (Vanderbilt Univ.)

The stellar superwind may be the last big event in a star's life, but there's more to come. Ultraviolet observations of the emerging star clearly show the presence of a "fast wind" whose speed is truly impressive — up to 350,000 mph (560,000 km/h) — but whose mass density is smaller than that of the superwind.

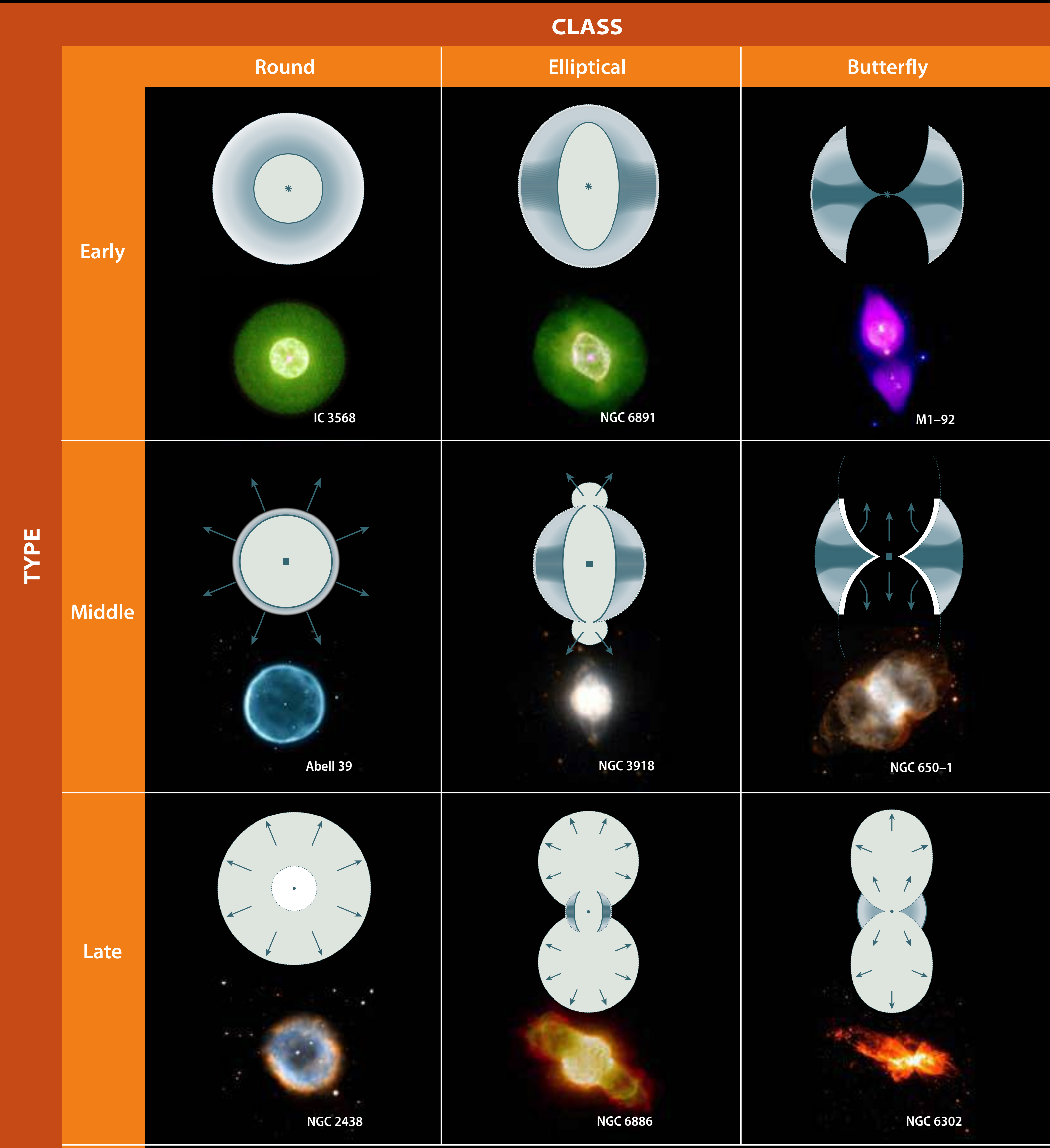
The fast wind quickly smashes into the slower wind ejected earlier, pushes the gas out of its way, and sears whatever gas it contacts. This effect creates the appearance of an empty cavity between the central star and the rest of the nebula. The cavity is no more empty than an inflated tire; it just looks that way.

Inside this illusionary cavity, we detect X rays from gas heated to a million degrees or more by the fast wind. At its perimeter, we find gas that has been scooped up into a thin rim. Beyond the rim lies a slow wind that has yet to sense the bubble's presence. Ultimately, the bubble pops when it reaches the outer edge of the slow wind, emptying its contents into the interstellar medium. As it does, it may scoop up much older gas the star had deposited when it was still a red giant. This can create large halos or pairs of bubble-like lobes.

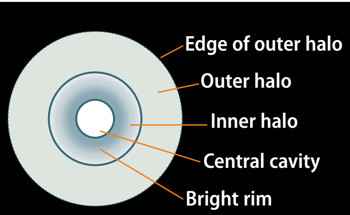
A planetary nebula "gets its certificate" when the central star becomes hot enough to ionize the preplanetary nebula. The fast wind peels away the star's cool outer layers and exposes hotter inner regions. So the star's surface becomes increasingly blue. This takes a few hundred to a few thousand years, after which the star's surface temperature reaches up to 100,000 K. For comparison, the Sun's surface is currently 5,800 K.

The small, hot surface of the dying star emits ultraviolet light before it starts

How astronomers classify planetary nebulae


CLASS
Round
Elliptical
Butterfly
TYPE
Early
Middle
Late
IC 3568
NGC 6891
M1–92
Abell 39
NGC 3918
NGC 650–1
NGC 2438
NGC 6886
NGC 6302

Astronomers have identified three types of planetary nebulae, along with three classes. Combinations allow for nine distinct shapes among these objects. The key image to the right shows the nebulae's main parts. All planetary nebula images courtesy of NASA/ESA/STScI; artwork: *Astronomy*: Roen Kelly after Bruce Balick


Edge of outer halo
Outer halo
Inner halo
Central cavity
Bright rim

to cool and fade away. The radiation strips electrons from atoms in the nebula. Suddenly, the nebula fluoresces and becomes easy to observe. The object's luminosity rises abruptly. Instead of reflecting a small portion of the star's total light, the nebula converts about half of the radiation into visible light. This brightening, coupled with their longer lifetimes and ever-growing diameters, make most planetary nebulae much easier to find than preplanetary nebulae.

Back to the puzzle board

The success of the first models of planetary nebulae elated astronomers in the 1990s, but it didn't last long. As Hubble produced more images, the complexity of the structures soon led to humility. We've made a good start, but the quest to understand the shapes of planetary nebulae continues. Of particular interest are the small knots, which don't readily form in the lovely, regular patterns. Another area of interest is planetary nebulae with more than one symmetry axis. And then there's the question of shapes.

The same shapes appear for planetary nebulae as for preplanetary nebulae — round, elliptical, and butterfly. However, half of the preplanetary nebulae are ellipticals with dust lanes cutting through their centers. For planetary nebulae, only 10 percent are bipolar, and none show dust lanes. Something happens to morph or distort their shapes, providing astronomers another challenge. Astronomers also wonder why planetary nebulae have such a narrow range of shapes.

The shapes are also strikingly symmetrical. One popular idea is that a companion star exerts a gravitational tug on the loosely bound outer layers of a red giant star, or perhaps the giant swallows its companion when it starts to bloat.

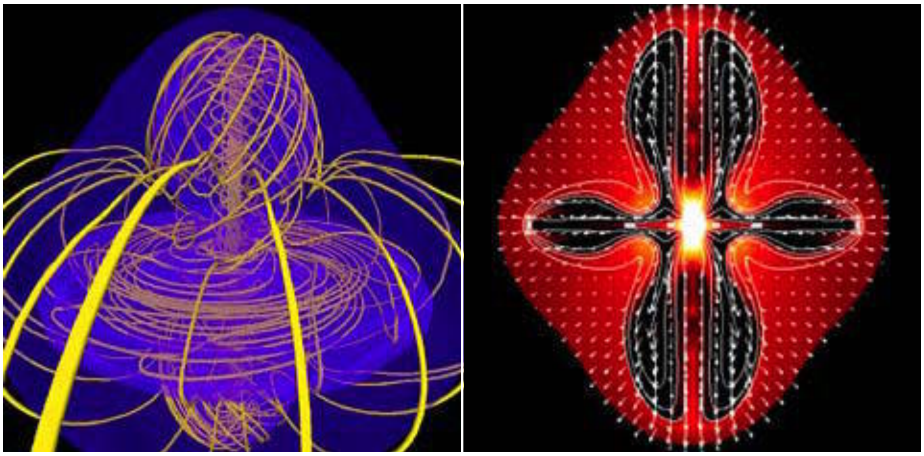
In the former case, the tidal forces on the outer layers drag them toward the rapidly orbiting companion star for the duration of the final helium flash. However, by the time the giant's material reaches the companion, it has moved on. So most of the material just keeps going outward in a spiral pattern, like water from a sprinkler. This forms a tightly wound one-armed spiral in a thin disk. Moreover, some of the material falls onto the companion and forms an accretion disk around it if the companion star is dense. Highly aligned outflows can arise from any accretion disk, even those in young stars, as the swirling material generates magnetic fields.

If the red giant swallows its companion, the small star acts like an eggbeater as it follows a spiral descent into the star's heart. This, too, will form a disk that shapes the nebula. But the merger of two orbiting stars can also account for other puzzling shapes of the final ejection.

First, the merger provides a way of extracting and harnessing the momentum of the companion's orbit and transferring it into the dense winds from which the planetary nebula forms. Second, the merger will disrupt the red giant's core. This might explain why the largest ejection is also the final one. In particular, an entire star's worth of hydrogen fuel landing on the extremely hot core might trigger a conflagration.

Another mechanism for shaping planetary nebulae may be magnetic fields released by convection. Red giants have deep convection, but generally not deep enough to dredge material out of the core. This changes during a helium flash. The extreme heat acts like a gas flame under a pot of water. The flash causes deep material to rise quickly. If that material consists of magnetized gas, as we expect, then, as the gas surfaces, the star ejects and distorts it while it's still connected to the star's spinning surface.

But field lines stretch like rubber bands. Magnetohydrodynamic (MHD) models, which study moving magnetized fluids, reveal strange behaviors. MHD models require huge computers, clever programming methods, and shrewd guesses about the ways magnetic fields permeate the gas and exit the star's surface. The enterprise is in its infancy, and results don't always agree, so it is premature to draw vast conclusions. However, the range of outcomes explains some of the more complex nebular shapes, except for one thing: The energies and momentums of the predicted outflows are smaller than the observations require.



Magnetic fields (left, yellow lines) become twisted as a star about to form a planetary nebula rotates. Charged particles spiral along the yellow lines as they flow outward. The fields guide these particles along the star's spin axis. The white and red regions of the right panel show where the particles will flow. The white rectangular area at the center is probably the only region sufficiently dense enough for Hubble to detect. Both images: Sean Matt (University of Virginia)/Adam Frank and Eric G. Blackman (Rochester University)

Looking forward

The beauty and symmetry of planetary nebulae please the eye and challenge the brain. We largely understand stellar evolution until the end. That's when we hit the limit of our understanding of the shapes and energies of mass-ejection. Stellar mergers and magnetized winds can solve some problems. New ideas will enter the discussion. For now, even with Hubble and other tools, it's too soon to tell if we're barking up the right trees.

Future instruments, especially the Atacama Large Millimeter Array (ALMA) under construction in Chile, will allow us to map the dust and possibly the magnetic fields in preplanetary nebulae. Such studies will provide essential data and propel the research for years to come. But for now, public, amateur, and professional astronomers will continue to enjoy the poetry of planetary nebulae even if we haven't figured out how stars manage to write it.

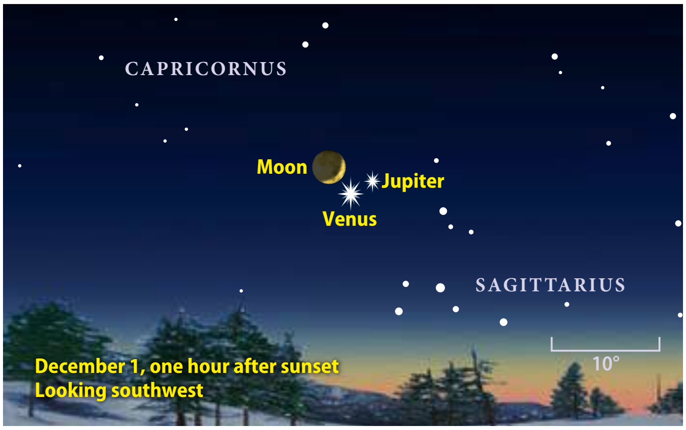
The sky this month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

December 08

A grand conjunction

When the Moon passes a planet, it offers a great photo opportunity. And two planets double the fun. On November 10, 2004, Venus (directly above the lunar crescent) and Jupiter played the Moon's foils. Steve Ellwood



A crescent Moon joins Venus and Jupiter December 1. The spectacular conjunction will have everyone hoping for a clear sky. *Astronomy*: Roen Kelly

44 **The Moon meets two planets** 👁 ∞ 🔭
49 **Meteor watch** 👁
49 **Rising Moon** 🔭
50 **When to view the planets** 👁 ∞ 🔭
50 **Titan joins Saturn** 🔭
50 **Comet search** 🔭
51 **Locating asteroids** ∞ 🔭
51 **Mercury joins Jupiter** 👁 ∞ 🔭

👁 **Visible to the naked eye**
∞ **Visible with binoculars**
🔭 **Visible with a telescope**

Venus and Jupiter stand next to each other in early December. This pair sparkles in the southwest after sunset, the unquestioned highlight of planet spotting this month. Still, their meeting is just one of three evening planetary conjunctions to wrap up the year.

Mercury joins Jupiter in the evening sky by month's end. Although not as stunning as the earlier pairing, these two make a fine punctuation for the year's end. And binocular viewers can catch Neptune in Venus' vicinity around Christmas. Binoculars are also the instrument of choice for spying Uranus after darkness falls, while crisp winter mornings will treat all observers to nice views of Saturn.

Although **Jupiter** and **Venus** lie far apart in space, they line up in spectacular fashion from our vantage point. On December 1, they stand a little more than 4 Moon-widths apart. (They were slightly closer on November's final evening.) Venus shines brilliantly at magnitude –4.2, while Jupiter lies to its upper right and appears noticeably fainter, at magnitude –2.0.

As if that weren't enough, the crescent Moon lies just 2.5° from Venus. Add a pretty foreground to the scene, and you can capture a gem of an image. The Moon and two planets have eastern Sagittarius as a backdrop. Observers with clear, dry air and a dark sky can add the Milky Way to the stunning scene.

Throughout December, Venus climbs higher in the sky, while Jupiter descends into the solar glow. Jupiter's slide toward a position behind the Sun arises mostly through Earth's orbital motion. Venus, on the other hand, circles the Sun faster than we do, so it's catching up. As Venus continues to swing around in its orbit, it loops away from the Sun, so we'll see it farther from our star in early 2009. Jupiter remains in Sagittarius throughout December, while Venus crosses Capricornus and ends the year in Aquarius.

You'll have a brief chance each evening to catch views of

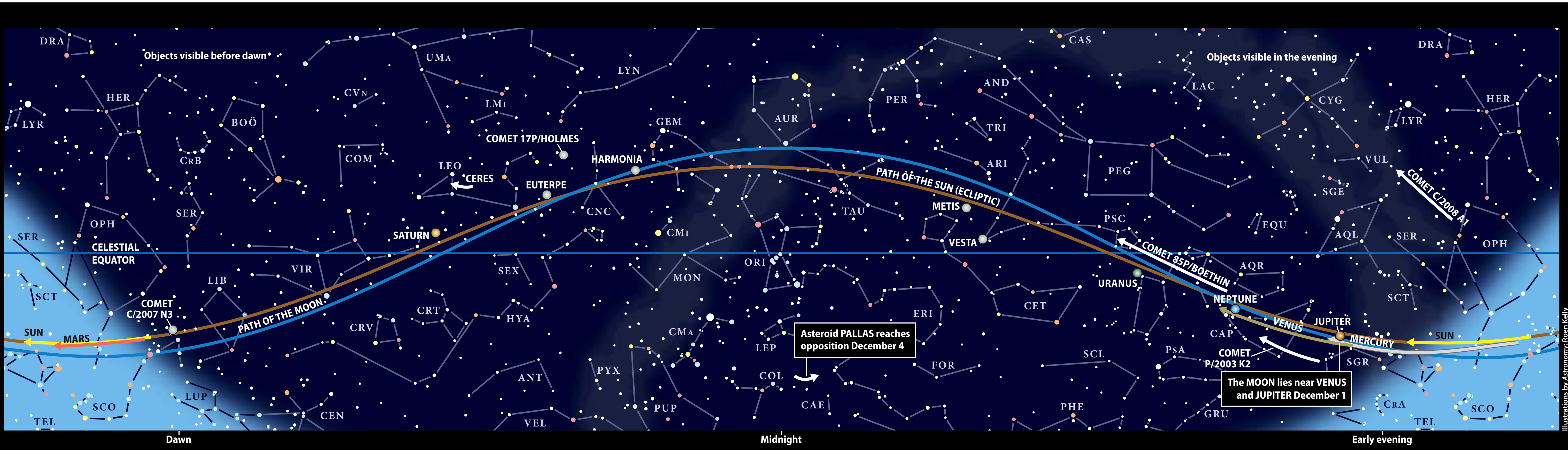
— *Continued on page 49*

Planets in December 08

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

Path of the planets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LEO
CERES
EUTERPE
SER
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Early evening

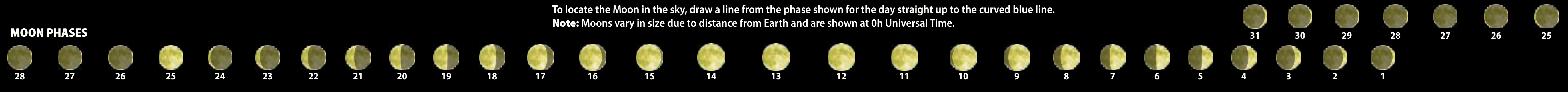
Asteroid PALLAS reaches opposition December 4

The MOON lies near VENUS and JUPITER December 1

Illustrations by *Astronomy*: Roen Kelly

MOON PHASES

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.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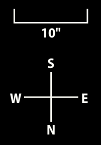
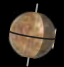
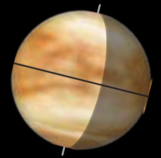
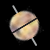
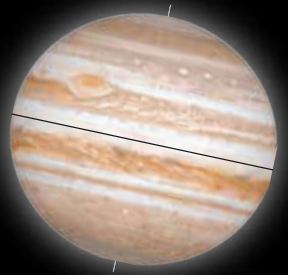
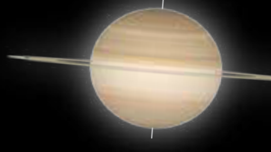
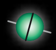
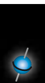
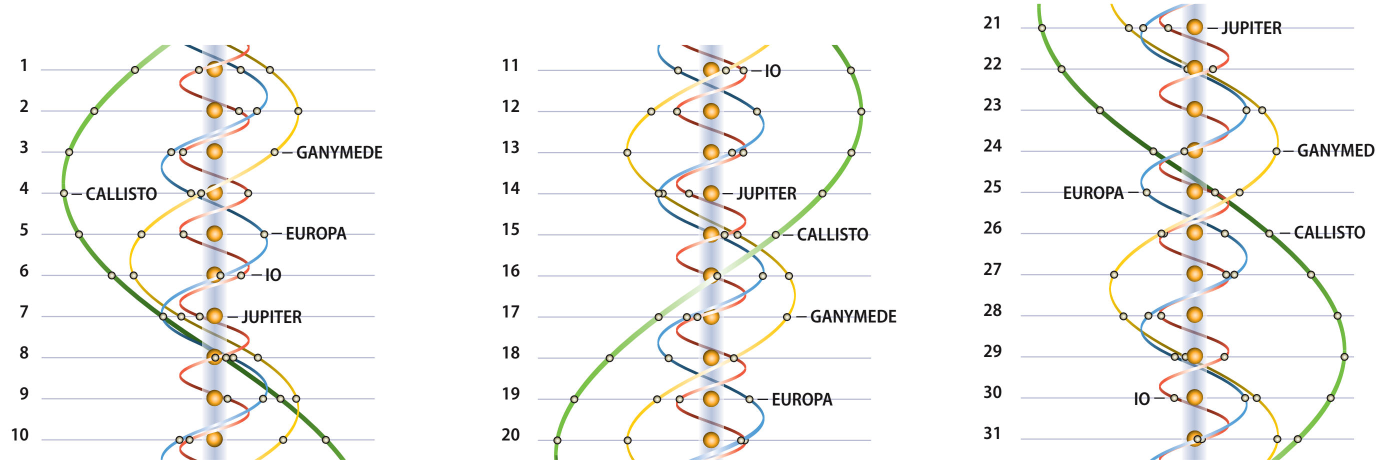


PLANETS	**MERCURY**	**VENUS**	**MARS**	**CERES**	**JUPITER**	**SATURN**	**URANUS**	**NEPTUNE**	**PLUTO**
Date	December 31	December 15	December 15	December 15	December 15	December 15	December 15	December 15	December 15
Magnitude	–0.7	–4.3	1.3	8.2	–2.0	1.0	5.9	7.9	14.1
Angular size	6.1"	18.3"	3.8"	0.6"	33.2"	17.9"	3.5"	2.2"	0.1"
Illumination	74%	65%	100%	96%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.101	0.911	2.462	2.157	5.931	9.278	20.152	30.536	32.539
Distance (AU) from Sun	0.355	0.725	1.479	2.553	5.120	9.362	20.099	30.034	31.568
Right ascension (2000.0)	20h02.0m	20h44.1m	17h19.4m	11h06.4m	19h48.0m	11h31.4m	23h19.8m	21h37.4m	18h02.1m
Declination (2000.0)	–22°13'	–20°25'	–23°40'	17°20'	–21°31'	5°14'	–5°09'	–14°33'	–17°43'

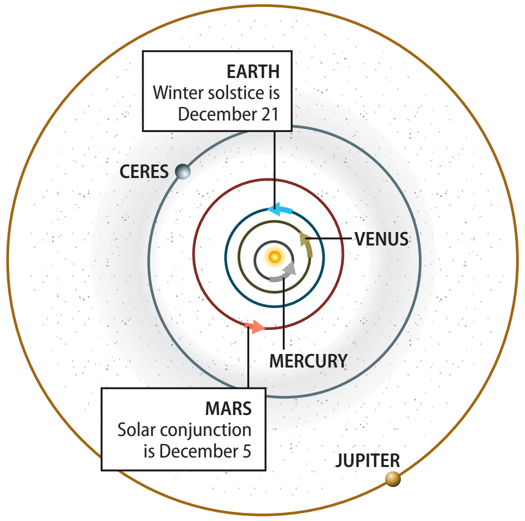
Jupiter's moons

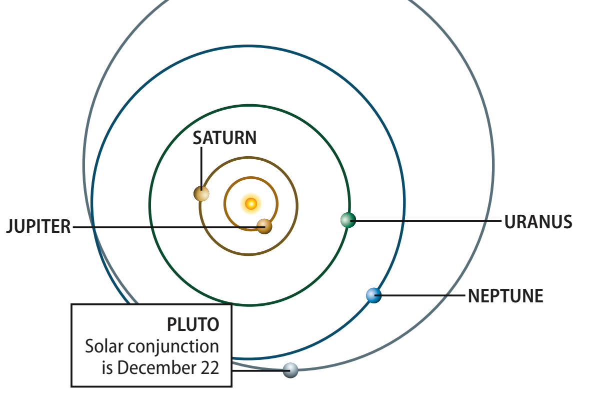
Dots display positions of Galilean satellites at 8 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during December.


EARTH
Winter solstice is December 21
CERES
VENUS
MERCURY
MARS
Solar conjunction is December 5
JUPITER


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO
Solar conjunction is December 22

StarDome

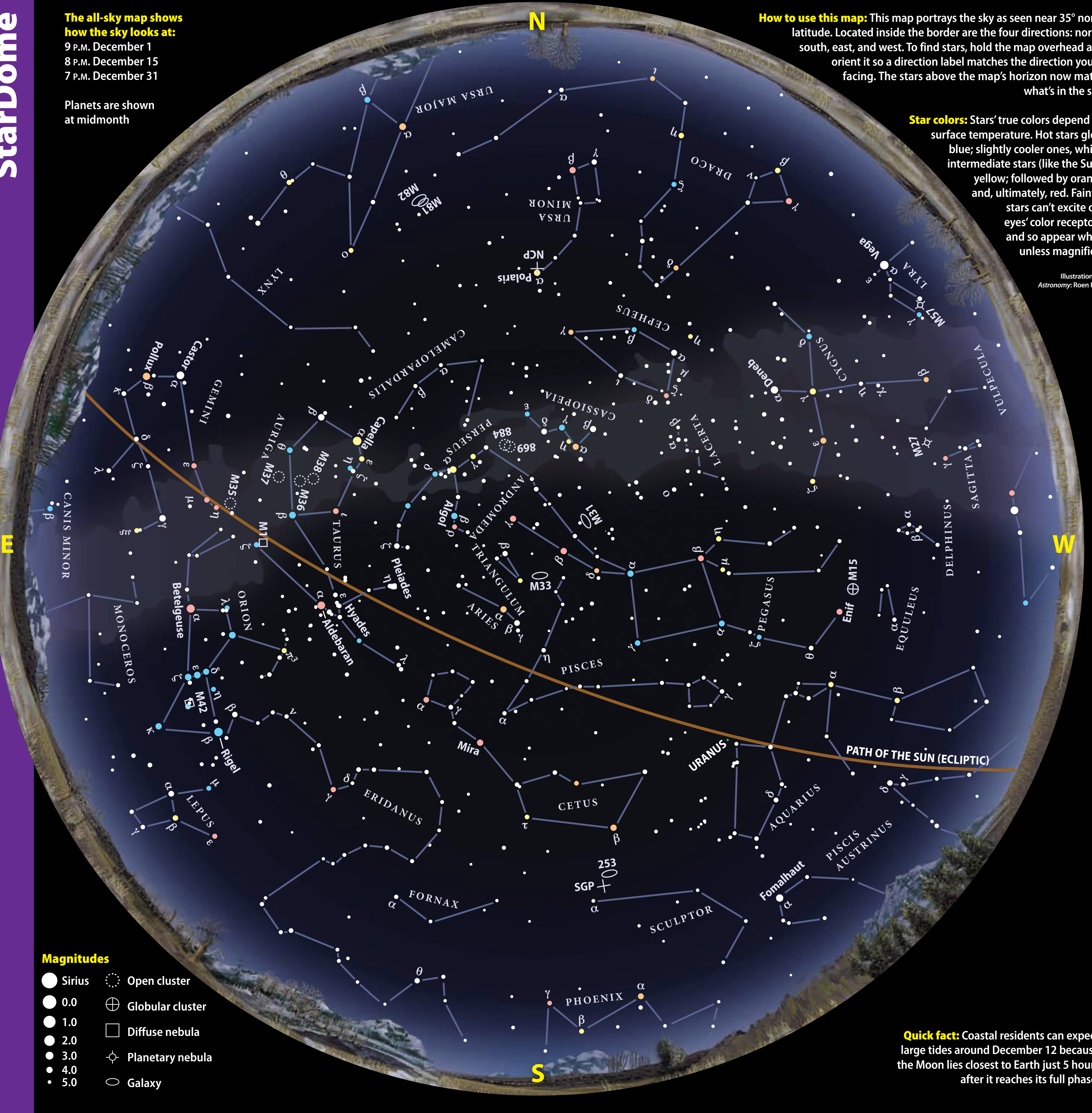
The all-sky map shows how the sky looks at:
9 P.M. December 1
8 P.M. December 15
7 P.M. December 31

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly


N
E
W
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URSA MAJOR
DRACO
URSA MINOR
NCP
Polaris
M81
M82
LYNX
Vega
LYRA
M57
CEPHEUS
CAMELOPARDALIS
Pollux
Castor
GEMINI
Deneb
CYGNUS
VULPECULA
CASSIOPEIA
LACERTA
M27
SAGITTA
PERSEUS
884
869
Capella
AURIGA
M37
M38
M36
M35
CANIS MINOR
ANDROMEDA
Algol
M31
TAURUS
M1
DELPHINUS
Pleiades
TRIANGULUM
M33
PEGASUS
M15
Enif
EQUULEUS
Betelgeuse
ORION
MONOCEROS
ARIES
Hyades
Aldebaran
PISCES
M42
Rigel
Mira
URANUS
PATH OF THE SUN (ECLIPTIC)
LEPUS
ERIDANUS
CETUS
AQUARIUS
PISCIS AUSTRINUS
253
SGP
FORNAX
Fomalhaut
SCULPTOR
PHOENIX

Magnitudes

● Sirius
● 0.0
● 1.0
● 2.0
● 3.0
● 4.0
● 5.0

○ Open cluster
⊕ Globular cluster
☐ Diffuse nebula
✧ Planetary nebula
⬭ Galaxy

Quick fact: Coastal residents can expect large tides around December 12 because the Moon lies closest to Earth just 5 hours after it reaches its full phase.

December 08

Note: Moon phases in the calendar vary in size due to distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Calendar of events

1 The Moon passes 1.3° south of Jupiter, 10 A.M. EST

Special observing date

1 A crescent Moon lies next to Venus and Jupiter after sunset.

The Moon passes 0.8° north of Venus, 11 A.M. EST

3 The Moon passes 1.4° north of Neptune, 10 P.M. EST

4 Asteroid Pallas is at opposition, noon EST

5 First Quarter Moon occurs at 4:26 P.M. EST

Mars is in conjunction with the Sun, 5 P.M. EST

6 The Moon passes 4° north of Uranus, 4 A.M. EST

12 Full Moon occurs at 11:37 A.M. EST

The Moon is at perigee (221,560 miles from Earth), 4:39 P.M. EST

13 Geminid meteor shower peaks

18 The Moon passes 6° south of Saturn, 10 P.M. EST

19 Last Quarter Moon occurs at 5:29 A.M. EST

19 Winter solstice occurs at 7:04 A.M. EST

22 Ursid meteor shower peaks

Pluto is in conjunction with the Sun, 4 A.M. EST

25 The Moon passes 0.09° north of Antares, 2 A.M. EST

26 The Moon is at apogee (252,650 miles from Earth), 12:46 P.M. EST

Venus passes 1.5° south of Neptune, 9 P.M. EST

27 New Moon occurs at 7:22 A.M. EST

28 The Moon passes 0.7° north of Mercury, 11 P.M. EST

29 The Moon passes 0.6° south of Jupiter, 4 A.M. EST

30 Venus passes 2° south of Jupiter, 8 P.M. EST

31 Mercury passes 1.3° south of Jupiter, 1 A.M. EST

The Moon passes 1.7° north of Neptune, 6 A.M. EST

The Moon passes 3° north of Venus, 4 P.M. EST

For definitions of terms, log onto www.Astronomy.com/glossary.

Astronomy magazine

— Continued from page 44

Venus and Jupiter through a telescope. Venus shows a 70-percent-lit disk early this month, but the phase shrinks noticeably as December progresses. By the 31st, when the crescent Moon rejoins Venus in the evening sky, the planet appears 58 percent lit. During the same time period, Venus' disk grows by 25 percent, from 17" to 21" across. This change in apparent size reflects Venus' motion toward Earth. It lies 94 million miles from us December 1, and 74 million miles away December 31.

Jupiter lies much farther away. On the 1st, it's far across the solar system and 540 million miles away. Even at this immense distance, Jupiter's disk spans 34" — double that of Venus. Unfortunately, Jupiter's low altitude means its atmospheric features will blur when viewed through a telescope. Sunlight reflected from Jupiter crosses the whole solar system unaffected, then becomes corrupted by our turbulent atmosphere in the last few dozen miles.

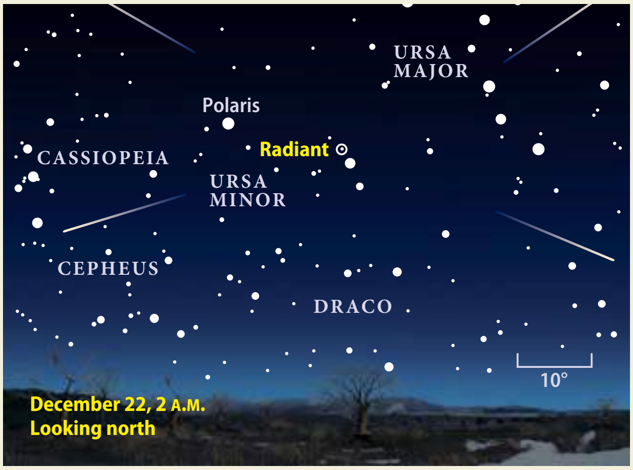
Such an affliction affects all astronomical observations from Earth's surface. One solution: Use a webcam to capture video frames quickly and freeze detail. Advanced image-analysis programs like *Registax* then allow you to pull out detail from the atmospheric blur.

Jupiter sets around 7:30 P.M. local time December 1, and by 6:15 P.M. on the 31st. Venus trends in the opposite direction. By month's end, the brightest planet sets well after 8 P.M. local time.

Mercury joins Jupiter for December's second planetary conjunction. You can spot the pair December 29, when a faint crescent Moon lies nearby. Jupiter will be easy to see shortly after sunset. If you need a guide, use Venus, which pops out of the fading twilight first. Jupiter lies some 25° to Venus' lower right. The slender crescent of a 2-day-old Moon appears 6° to Jupiter's upper left. Mercury, shining at magnitude –0.7, lies 2° below Jupiter.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc. in Nashua, New Hampshire.* **Alister Ling** *is a meteorologist for Environment Canada.*

Meteor watch



The Ursid meteor shower should deliver at least 5 meteors per hour — and perhaps significantly more. *Astronomy*: Roen Kelly

A bear of a winter shower

The Ursid shower doesn't usually rank at the top of December's meteor calendar, but it does this year. The shower peaks before dawn December 22, and remains active from the 17th to the 26th. New Moon occurs December 27, so it won't pose a significant problem during the prime observing hours after midnight.

The Ursids' radiant lies in Ursa Minor, so it's up all night. Rates typically run about 5 meteors per hour, but the shower occasionally has strong bursts when 30 or more meteors per hour occur.

Observers last noticed enhanced activity in 2006. If the rate spikes again this year, it's likely to happen between about 2:30 A.M. and 4:30 A.M. EST December 22. The Ursids parent comet, 8P/Tuttle, last appeared in our skies this past January. Astronomers don't know if that will increase this year's activity.

The normally spectacular Geminid meteor shower gets washed out this year. It peaks the evening of December 13, just 1 day after Full Moon. It will mask all but the brightest meteors.

Rising Moon

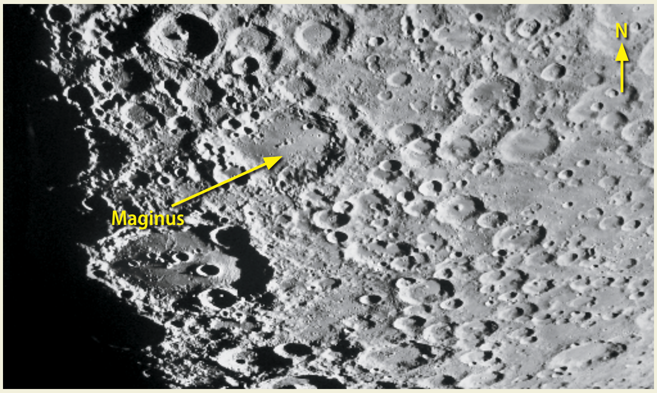
The odd ray of Maginus

On December 5, you should see a ray of sunshine spreading across the floor of the battered crater Maginus. Scarps like the Straight Wall, rilles, and domes all depend on their height to cast dark shadows down onto the surrounding plains. In complete contrast, 100-mile-wide Maginus sports a bulged-up floor, central peaks, and — most crucially — a low rim. This allows a glorious V-shaped splay of sunlight to burst across the crater's dark floor.

Like so many events in astronomy, timing is everything. On December 4, Maginus lies in complete darkness. And by the 6th, the Sun has risen high enough to illuminate almost all of the crater's floor. Fortunately, the sunlight ray remains visible for several hours the evening of December 5.

Don't confuse this use of the word "ray" with the common ejecta rays seen at Full Moon. Ejecta rays come from large impacts that spread lighter-hued material in long lines across the Moon's face. The most spectacular ejecta rays emanate from the crater Tycho.

Maginus lies modestly deep in the Moon's southern hemisphere, just slightly northeast of the larger, more prominent crater Clavius.

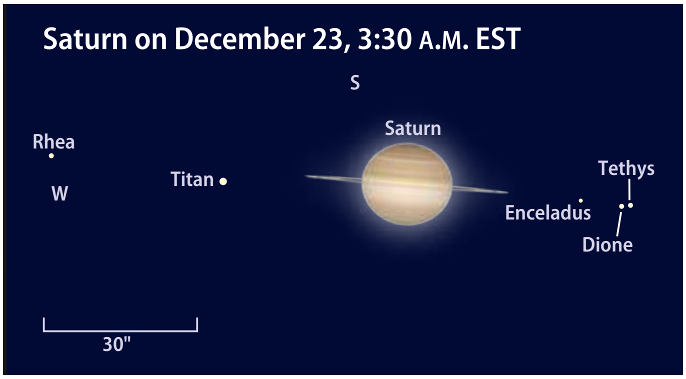


Old and battered, the 100-mile-wide crater Maginus lies deep in the Moon's southern hemisphere. *Consolidated Lunar Atlas*/UA/LPL

Located at a latitude of 50° south, Maginus appears closer to the limb than you might think because of the foreshortening effect of the globe curving away from us.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Saturn (east)	Saturn (south)
Venus (southwest)		
Jupiter (southwest)		
Uranus (south)		



Saturn's moon Titan appears prominent next to the planet's disk December 23, even though the planet's rings won't show up well. *Astronomy*: Roen Kelly

On the following evening, Mercury passes due south of Jupiter. And on New Year's Eve, they appear side by side, glowing like a pair of eyes in the twilight. They could be a Cheshire cat without the smile. To see a smile, look for the now-obvious crescent Moon, which stands above the pair and adjacent to Venus. Mercury will remain on view for the first week of 2009, helping to usher in the International Year of Astronomy.

December's third planetary conjunction will be much harder to see. **Neptune** joins Venus in the same binocular field December 26. (They'll also appear in the same field the evening before and after, but they'll be more widely spaced.) Bring Venus to the lower center of your binocular field, then try to spot Neptune 1.5° to the north. Neptune glows dimly at magnitude 8.0. A distinctive line of three brighter stars lies east of Neptune and will help you to identify the planet. Each night during December, Neptune creeps ever-so-slowly toward these stars, which lie northeast of 4th-magnitude Gamma (γ) Capricorni.

You also should use binoculars to track down **Uranus**. It's easier to see than Neptune and lies one constellation farther east, in Aquarius. Uranus spends the first 2 weeks of December next to the 6th-magnitude star 96 Aquarii. Less than 10' separates the two. For comparison, this is closer than the distance between Mizar and Alcor, the well-known double star in the Big Dipper's handle.

Uranus ended its westward (retrograde) motion relative to the background stars in November and has now begun to trek eastward again. During December's first 2 weeks, Uranus and 96 Aquarii will be fascinating to watch as their relative positions shift night to night. The pair will look like a rapidly revolving double star. On December 1, Uranus lies due south of 96 Aqr. Two weeks later, the planet will arrive due east of the star. And by the time December closes, Uranus lies 30' east-northeast of 96 Aqr.

It may seem as though the evening sky has all the planets, but mornings hold one important straggler. **Saturn** rises by 1 A.M. December 1 and stands high in the south during the predawn hours. You can find it near the border between Leo and Virgo.

Shining at magnitude 1.1, Saturn appears dimmer now than at any time this year. Most of the light we see coming from the planet reflects off

Comet search

Boethin beckons telescope users

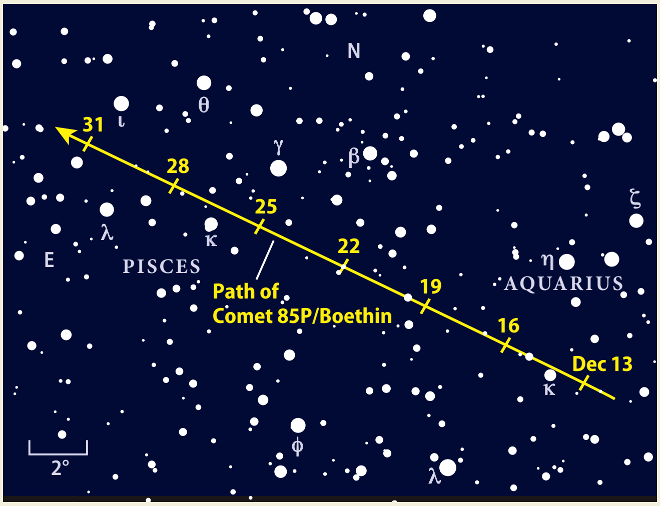
What could be better than a well-placed comet in the evening sky? A brighter one, of course, but Comet 85P/Boethin glows respectably at 7th or 8th magnitude this month. This makes it accessible from suburban backyards with a 4-inch scope.

As the sky darkens around suppertime, this periodic visitor lies due south and more than one-third of the way from the horizon to the zenith. Neptune and Uranus also lie in this watery part of the celestial sphere, so plan to take a couple of star charts with you and find them as well.

Unless the comet erupts unexpectedly, this will be as bright as it ever gets. Boethin reaches perihelion, the closest point to the Sun in its elliptical orbit, in mid-December. It then lies just outside Earth's orbit right when we're passing by on the inside track.

This geometry also explains Boethin's missing tail. This gossamer scarf flapping in the solar wind angles away from the Sun and thus appears behind the comet's head from our point of view. Through a telescope, Boethin should show a roundish, diffuse glow, similar in appearance to the elliptical galaxy M87 in Virgo but brighter by a magnitude. In contrast to the galaxy, whose perimeter brightness drops off evenly, the comet should sport a well-defined edge.

Use a range of magnifications to see all of the comet's features. At high power, you might even glimpse the "false nucleus," a pinprick shining in the middle of the brightest glow. The true surface of this dirty snowball lies hidden behind several bright layers of dust ejected in the previous several days.



Comet 85P/Boethin should peak at 7th magnitude this month. You can find it among the background stars of Aquarius and Pisces. *Astronomy*: Roen Kelly

Locating **asteroids**

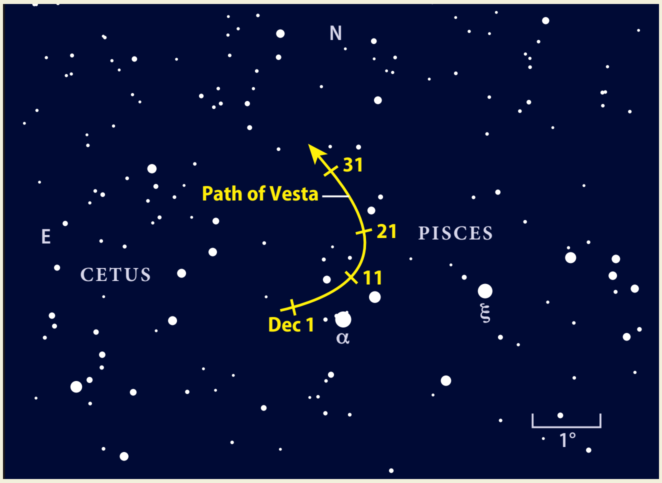
Vesta swims with the Fishes

One of the sky's nicest gifts this month is an easy way to find and track the large asteroid 4 Vesta. This space rock remains within 1 binocular field of the 4th-magnitude star Alpha (α) Piscium, which lies halfway up in the southeastern sky during early evening.

From a suburban backyard, you can spot the 7th-magnitude asteroid without much effort. Apart from Alpha, only three other stars in the area shine brighter than Vesta. From December 7 to 9, Vesta appears near the vertex of an equilateral triangle of these stars, the brightest of which is Alpha itself. Return every couple of evenings and you will notice one of the dots — Vesta — has shifted position.

Under a bright urban sky, however, you'll be challenged to spot Alpha with your naked eyes, and Vesta may even be out of binocular range, obscured by the veil of artificial light.

While you're in this area, point your scope to Alpha and crank up the magnification to 120x or more. This star is a binary system whose stars take about 930 years to orbit each other. The primary shines at magnitude 4.2 and the secondary a magnitude fainter. The stars lie 1.8" apart, near the limit of a 3-inch scope for a typical observer.



Asteroid Vesta moves slowly this month as it reaches the end of its retrograde loop. You can find it with binoculars near the 4th-magnitude star Alpha (α) Piscium. *Astronomy*: Rowen Kelly

its disk — the rings add essentially nothing. Earlier this year, the rings contributed a few tenths of a magnitude to the brightness. Now they appear almost edge-on, with just 1° of tilt throughout December. They will open up a bit in early 2009 before turning precisely edge-on to our view next summer.

With the rings nearly edge-on, we get a rare view of Saturn's entire disk. Any small telescope will show that the disk appears flattened. In mid-December, the planet's equatorial diameter spans 18" while the polar diameter measures 16". The planet's fast rotation causes this flattening.

Normally on Saturn, the rings partially shadow one hemisphere; but not now — both hemispheres receive full sunlight. Watch for any changes in the appearance of the planet's atmosphere. Subtle bands wrap around the disk, and storms occasionally appear. The storms show as bright spots on the disk. Saturn spins on its axis in a little more than 10 hours, so storm movements become obvious within 15 minutes.

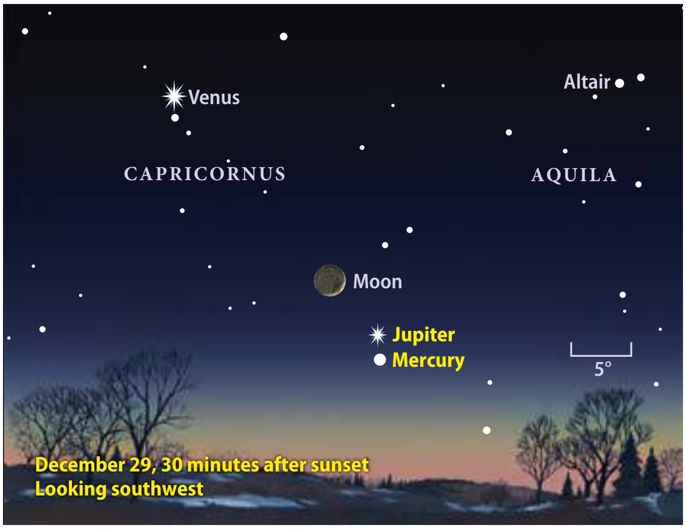
With the rings now almost edge-on, Saturn's moons cross in front of and behind the planet as they orbit. For telescope viewers, transits of Titan show up best, although video recording can capture some of the fainter moons during transits. Viewers in North America won't be able to see any of this month's Titan transits, but this moon does appear close to Saturn December 6, 7, 14, 15, 22, 23, 30, and 31.

Distant Iapetus, one of Saturn's most intriguing moons, reaches greatest eastern elongation December 7. It then glows faintly at 12th magnitude. The moon swings due north of Saturn December 26, brightening as it heads westward. At greatest western elongation in early 2009, when its brighter face turns in our direction, we see it glowing at 10th magnitude.

A nearly Full Moon occults the Pleiades star cluster (M45) the night of December 10/11. The bright Moon cuts across the northern part of the cluster, although our companion's brilliance makes it difficult to spot the stars as they disappear. Nevertheless, you should have fun viewing these events, particularly when the Moon occults several 4th-magnitude stars. View these occultations with a high-power eyepiece, which reduces the acreage of the Moon visible through your telescope. For the timing of individual events from your location, you can check out www.lunar-occultations.com.

Earth's winter solstice occurs December 21 at 7:04 A.M. EST. The Sun then reaches its southernmost declination along the ecliptic, resulting in the Sun's lowest noontime altitude of the year for everyone in the Northern Hemisphere. Meanwhile, summer is beginning in the Southern Hemisphere.

Coincidentally, Earth's elliptical orbit carries us to perihelion, our closest point to the Sun, just 2 weeks later. Earth's seasons result from the tilt of our planet's axis, which causes the Sun to appear at different altitudes, and not from the Sun's distance.



December 29, 30 minutes after sunset
Looking southwest

Mercury joins Jupiter in the month's second naked-eye planetary conjunction. The Moon lies near the pair after sunset December 29. *Astronomy*: Roen Kelly

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2009 Winter Sweepstakes

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2. Sweepstakes Entry. Enter online by filling in the Online Entry Form and hitting the SUBMIT ENTRY key, or mail in a postcard with your name, address, city, state or province, and zip or postal code to: The *Astronomy* 2009 Winter Sweepstakes, P.O. Box 378, Waukesha, WI 53187-1199. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for The *Astronomy* 2009 Winter Sweepstakes will be December 19, 2008, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around February 17, 2009 for the following awards: One (1) Grand Prize consisting of a Meade® 10" LX90-ACF™ Telescope (retail value $2,799.00). One (1) First Prize consisting of a Meade® 8" LDX-75™ Schmidt-Newtonian (retail value $1,199.00). One (1) Second Prize consisting of a Meade® EXT-125PE (retail value $899.00). One (1) Third Prize consisting of a PST Solar Telescope (retail value $599.00). One (1) Fourth Prize consisting of a mySKY® Plus (retail value $299.00). Ten (10) Fifth Prizes consisting of a subscription to *Astronomy* magazine (retail value $42.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for *Astronomy* magazine is 124,365. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* 2009 Winter Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Company. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing Co. and will not be returned.

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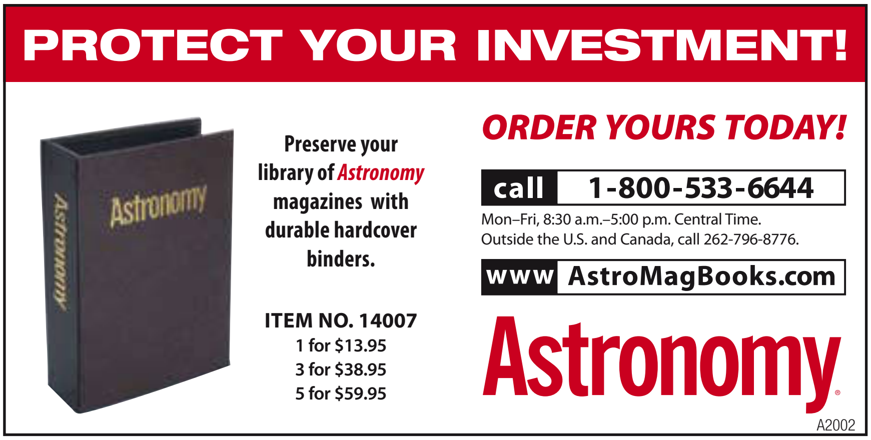
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Extreme organisms on Earth show us just how weird life elsewhere could be. **by Chris Impey**

How **life** could thrive

Humans have left their mark all over Earth. We're proud of our role as nature's generalists — perhaps not as swift as the gazelle or as strong as the gorilla, but still pretty good at most things. Alone among all species, technology has given us dominion over the planet. Humans are endlessly plucky and adaptable; it seems we can do anything.

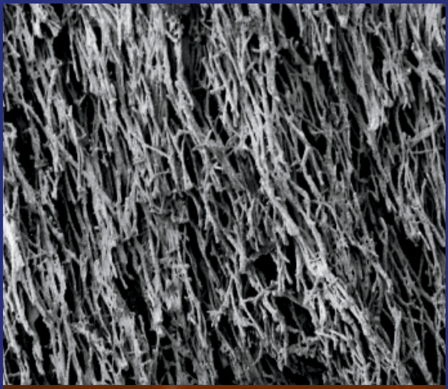
Yet in truth, we're frail. From our safe living rooms, we may admire the people who conquer Everest or cross deserts. But without technology, we couldn't live beyond Earth's temperate zones. We cannot survive for long in temperatures below freezing or above 104° Fahrenheit (40° Celsius). We can stay underwater only as long as we can hold our breath. Without water to drink we'd die in 3 days.

Microbes, on the other hand, are hardy. And within the microbial world lies a band of extremists, organisms that thrive in conditions that would cook, crush, smother, and dissolve most other forms of life. Collectively, they are known as extremophiles, which means, literally, "lovers of extremes."

Extremophiles are found at temperatures above the boiling point and below the freezing point of water, in high salinity, and in strongly acidic conditions. Some can live deep inside rock, and others can go into a freeze-dried "wait state" for tens of thousands of years. Some of these microbes harvest energy from methane, sulfur, and even iron.

The study of extremophiles has taught scientists that life has evolved on Earth to colonize even the most inhospitable environments. And if they can do it here, why can't they do it out there — in the extremes of cold, pressure, and radiation beyond Earth?

As NASA prepares to spend billions on the search for life in the solar system, it's worth recalling the exotic and weird life right under our noses. We have much to learn from extremophiles that could assist and inform the search for life elsewhere.

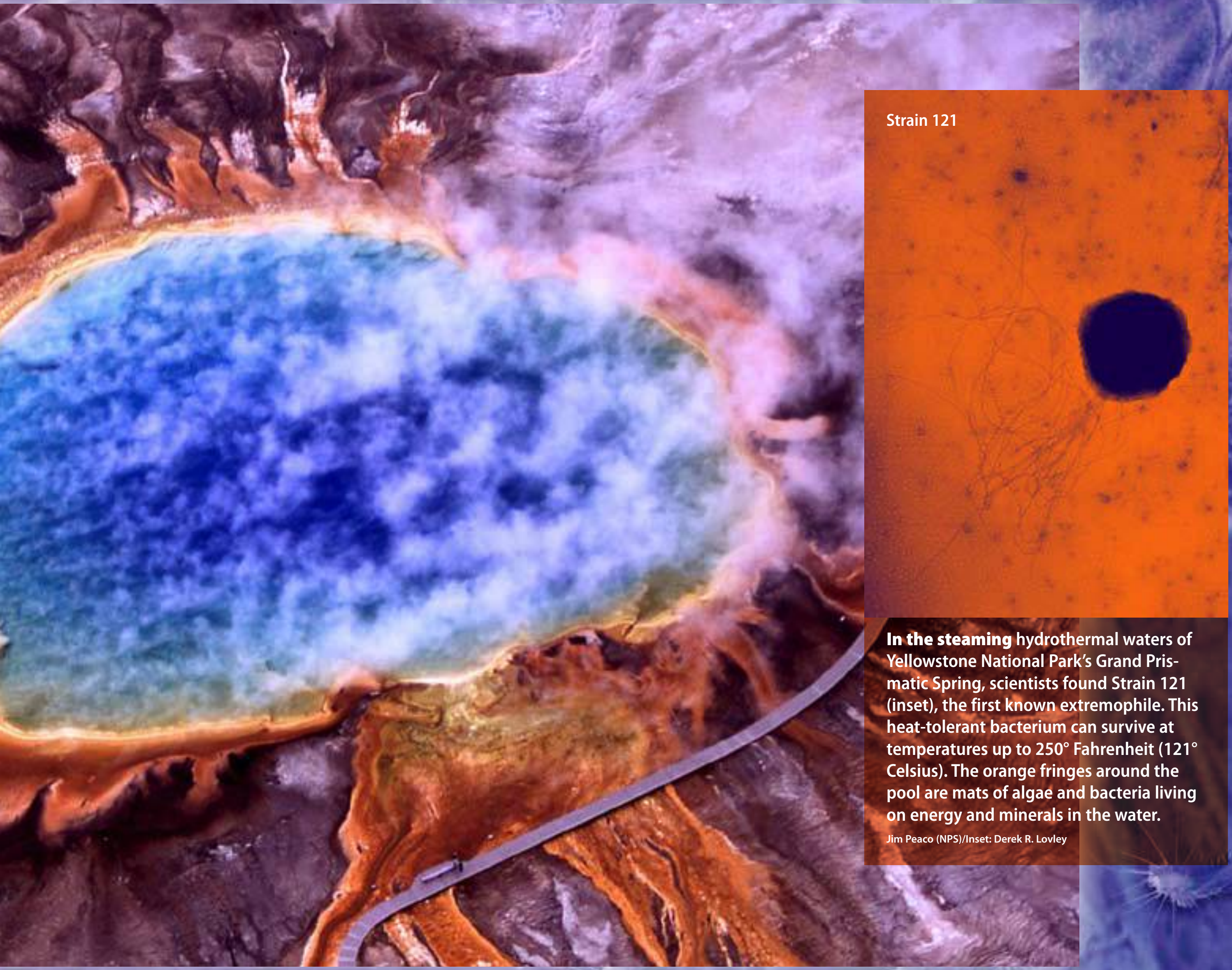


Silica minerals coat bacterial filaments in a sample from the Grand Prismatic Spring in Yellowstone National Park. Scientists hunting for martian microorganisms could search for similar structures in fossilized hot spring deposits. Arizona State University/Jack Farmer

Extreme origins

Earth is a microbial planet, and the common ancestor of all life on Earth

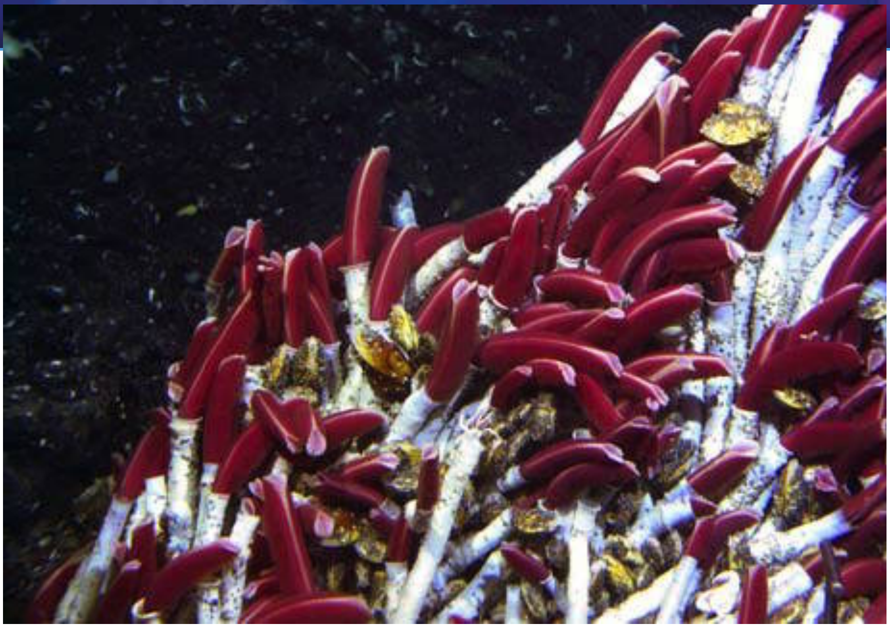
on **hostile** worlds



In the steaming hydrothermal waters of Yellowstone National Park's Grand Prismatic Spring, scientists found Strain 121 (inset), the first known extremophile. This heat-tolerant bacterium can survive at temperatures up to 250° Fahrenheit (121° Celsius). The orange fringes around the pool are mats of algae and bacteria living on energy and minerals in the water.

Jim Peaco (NPS)/Inset: Derek R. Lovley

Background montage *Astronomy:* Kellie Jaeger



The deep-sea tube worms in this image live on hydrothermal vents along the Pacific Ocean's Galápagos Rift. The worms live symbiotically with bacteria in their guts: The bacteria use hydrogen sulfide gas spewing from the vents as a source of energy and, in the process, make carbohydrates for the worms. Woods Hole Oceanographic Institution

was probably a heat-loving extremophile. When scientists resurrected proteins from these ancestral bacteria for study in the lab, the organisms performed best at a sizzling temperature of 150° F (65° C).

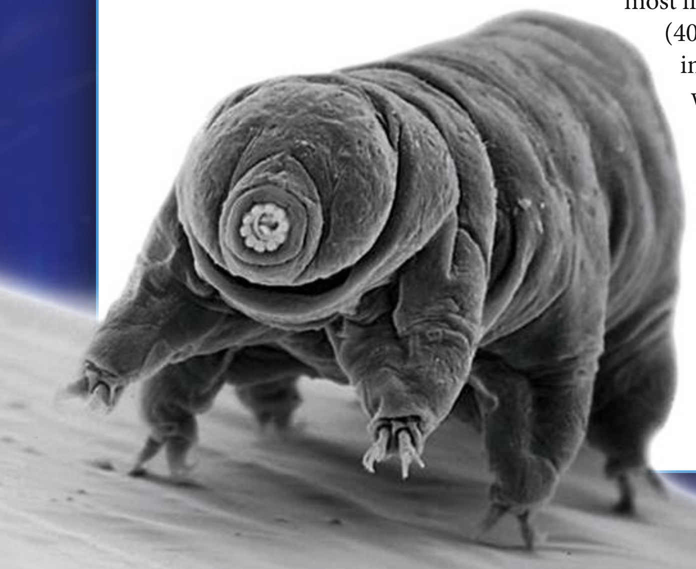
Early Earth was as hostile and inhospitable as Dante's hell. Visualize lightning, steam, a rain of meteorites, and a surface covered with magma and sulfur. This doesn't exactly bring to mind Darwin's "warm little pond."

Think of extremophiles as stouthearted little biological superheroes, doing heroic jobs under nearly impossible conditions. If it helps, imagine them clad in tiny masks and capes and booties, though in practice most of them are nearly spherical and unexceptional in appearance.

The names of extremophile categories convey their particular characteristics, so they're not quite as catchy as the names of comic superheroes. There's Thermophile, who emerges from the boiling inferno unscathed. There's Psychrophile, who shrugs off extreme cold. There's Endolith, who does his best work encased in rock. There's Acidophile, who energizes by bathing in battery acid. And there's Barophile, who withstands pressures that would bring lesser superheroes to their knees.

Extremophiles were first discovered in the hot springs of Yellowstone National Park just over 40 years ago. Yellowstone is still the prototypical site for the study of microbes with resistance to high temperature and acidity.

As the temperature of water rises, most life gets into trouble. At 104° F (40° C), oxygen won't dissolve well in water, so organisms like fish will die. Above 167° F (75° C), chlorophyll breaks down, making photosynthesis impossible. Above 212° F (100° C) — the boiling point of water at sea level — cells normally can't control the flow of molecules in and out. At the boiling point, DNA and proteins unfold and no longer function.



Tardigrades, a group of tiny organisms called water bears, include more than 750 species and live in the most extreme environments on Earth. This member of a class of tardigrades, Macrobiotus tonollii, hails from Roan Mountain, Tennessee.

Diane R. Nelson

With certain extremophiles, high temperatures are less of a challenge. The reigning champion thermophile, dubbed Strain 121, continues to grow when it's as hot as 250° F (121° C). Extremophiles near deep-sea hydrothermal vents might even withstand superheated water over 390° F (200° C), although this is still unconfirmed.

Thermophiles survive by reaching deep into the chemical toolbox for adaptive strategies. For example, they use only the sturdiest enzymes, they ingest salts that shield the DNA double helix, and they incorporate saturated fats to bolster their cell membranes.

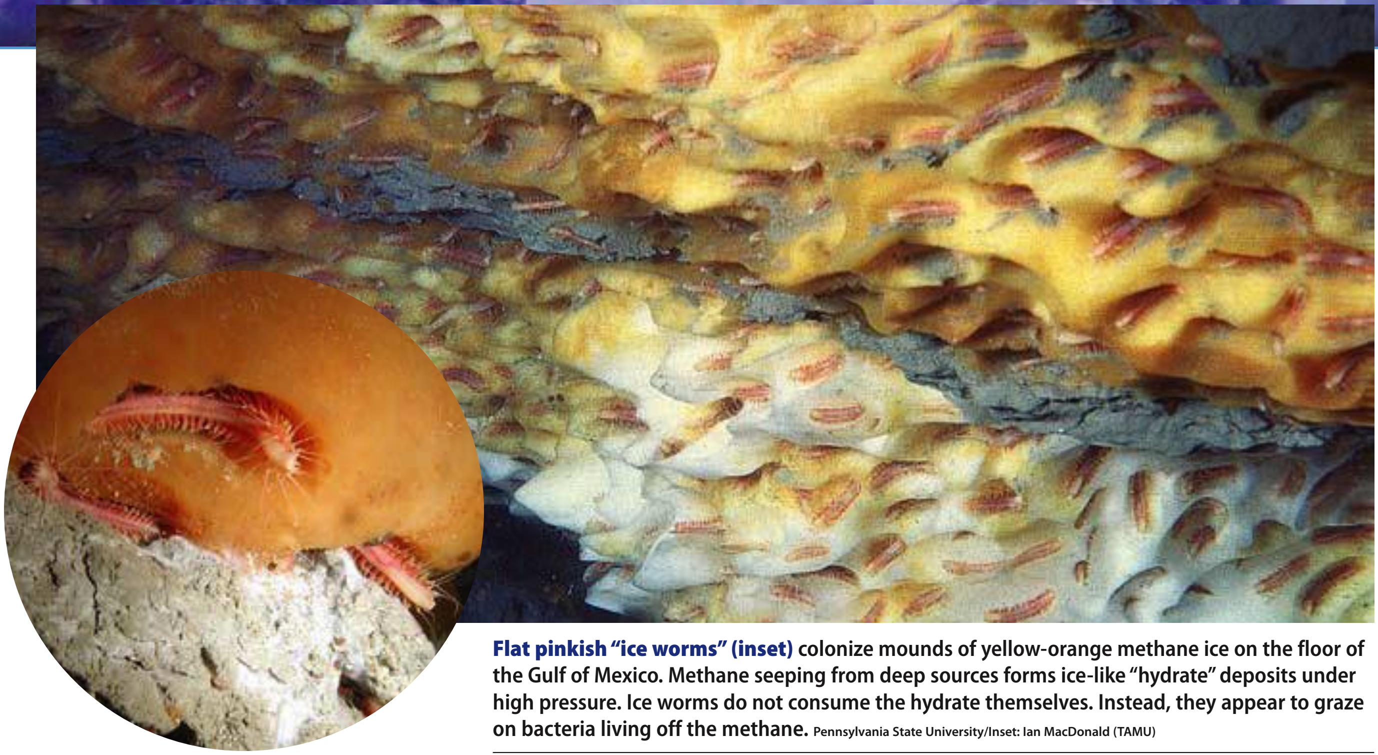
Heat tolerance is a legacy of the conditions on early Earth. These deep-sea survivors may have ridden out the heavy meteorite bombardment that wreaked havoc with surface dwellers early in Earth's history.

The big chill

At low temperatures, chemical reactions slow down and life gets sluggish. When water freezes, it expands by 10 percent and causes cells to rupture. Yet there is a type of nematode — tiny, wormlike creatures — that can survive even being frozen.

Organisms ranging from microbial colonies to the tiny insect called a Himalayan midge remain active down to −0.4 F° (−18° C). Some organisms do it by insulating themselves from the external environment with fat-soluble molecules called lipids. Others take in salts that act like antifreeze. Many cell lines remain viable but inactive in liquid nitrogen at −320° F (−196° C).

Biodiversity in the coldest parts of the world is amazing. In polar regions, algae are so numerous they often color the ice green. Tiny, swimming crustaceans called krill outweigh the combined bulk of all humans on the planet.



Flat pinkish "ice worms" (inset) colonize mounds of yellow-orange methane ice on the floor of the Gulf of Mexico. Methane seeping from deep sources forms ice-like "hydrate" deposits under high pressure. Ice worms do not consume the hydrate themselves. Instead, they appear to graze on bacteria living off the methane. Pennsylvania State University/Inset: Ian MacDonald (TAMU)

We think water is essential for life, yet some organisms survive with surprisingly little of it. Chile's Atacama Desert and Antarctica's high valleys are so dry they're a perfect lab for scientists who test equipment and experiments intended for Mars. Yet a small variety of lichens and insects survive in these arid environments, where it may not rain for decades at a stretch.

Making do with little is one thing, but there's another strategy when the drying is total. Rather than just giving up, organisms maintain a breezy optimism by going into hibernation. Some spores and cysts appear to be able to survive for a million years in suspended animation, and bacteria manage the same trick when they're trapped in salt crystals. To reanimate, just add water!

Living under pressure

Pressure is also no problem for creatures that have adapted to it. Finding life in the deep sea has strongly influenced thinking about extremophiles beyond Earth because their discovery was so unexpected. For this, we can thank a submersible called Alvin.

Alvin is the size of a small SUV and cruises at a plodding 1 knot (1.2 mph), but its titanium hull can withstand the mountainous weight of an entire ocean. In 1977, Alvin's crew discovered hydrothermal vents off the Galápagos Islands at a depth of 1.6 miles (2.5 kilometers).

The crew was amazed to find a thriving ecosystem that lived without solar energy. Three hundred species congregated near superheated water from "black smoker" vents. The creatures ranged from bacteria and iridescent shrimp to giant clams and 6-foot-long (2 meters) red-tipped worms. The base of this ecosystem consists of bacteria living off hydrogen sulfide gas spewing from the vents.

Recent discoveries add the important information that not all life on the deep seafloor requires hydrothermal heat. For example, pink "ice worms" burrow into mounds of ice-like methane hydrate on the floor of the Gulf of Mexico, possibly feeding on methane-metabolizing bacteria.

Titans of toxicity

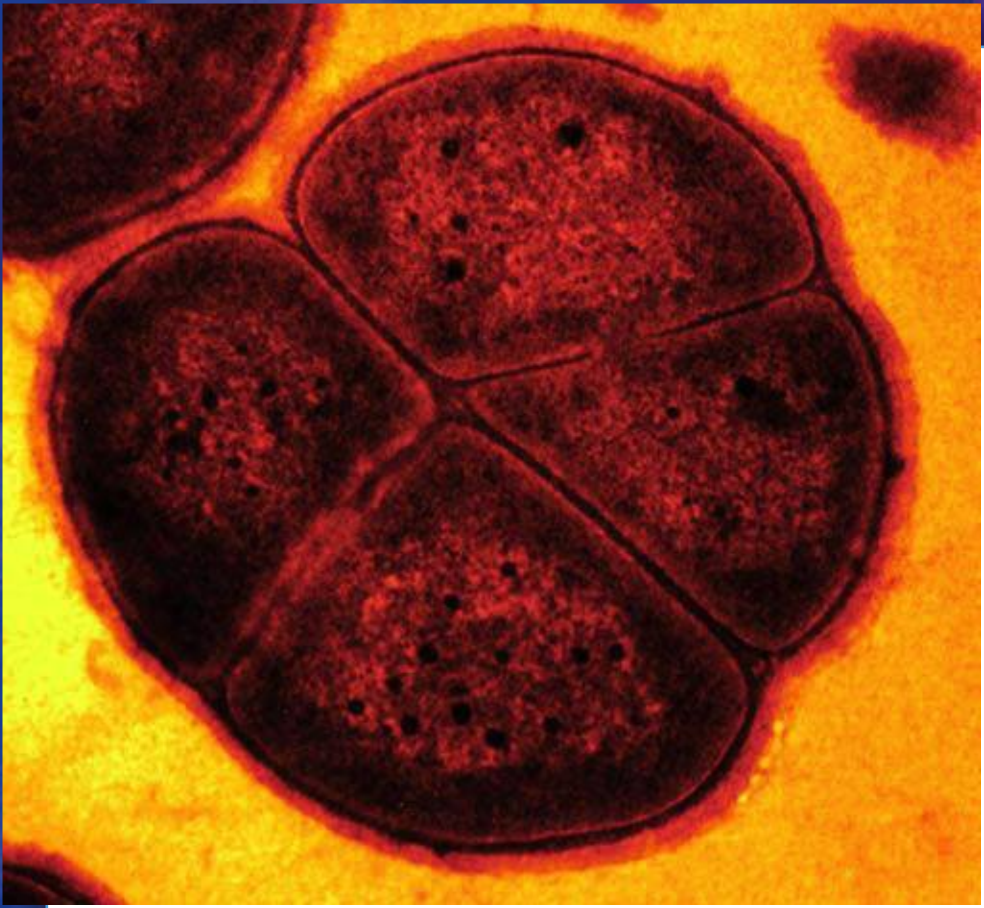
Extremophiles can also tolerate lethal chemical conditions. If you were adrift at sea in a small boat with no supplies, you might just get desperate enough to drink seawater. And you would die. Seawater causes dehydration by increasing the pressure inside cells. Water exits through cell membranes, and the DNA inside breaks down.

But salt-loving microbes make their homes in salt flats, inland seas, and briny pools on the seafloor. They use charged molecules (ions) and simple sugars to protect their cell functions. Algae called Dunaliella salina handle salinity 10 times that of seawater. Beyond this concentration, salt actually precipitates out of solution.

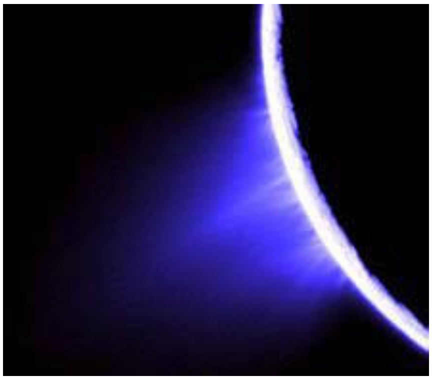
Extremophiles also push the edges of the 14-point pH scale, which describes the concentration of hydrogen ions in a solution. This is important for biological processes because hydrogen ions' electrical charge drives chemical reactions. The pH of pure water is 7, and our cells can't stray far from this without serious dysfunction. A substance with a pH below 7 is an acid; a substance with a pH above 7 is a base.

Acid test

Miners first worked the The Iron Mountain mine near Mount Shasta in Northern California in the 1860s gold rush. It has since become one of the U.S. Environmental Protection Agency's worst toxic sites. When pyrite minerals (iron sulfide) in mining waste rock interact with water and oxygen, they produce sulfuric acid. The acid runoff has, in turn, leached out heavy metals like arsenic, cadmium, and zinc.



In this scanning-electron microscope image, four individual bacteria form a "tetrad" of the species Deinococcus radiodurans. The microorganism's talent for fast DNA repair allows it to withstand radiation levels that would quickly extinguish most other Earth life. Michael J. Daly (UHSUHS)



Cassini Orbiter flybys of Saturn's moon Enceladus revealed watery geysers spewing from fractures. The water temperature, at 32° Fahrenheit (0° Celsius), is potentially more hospitable to life compared to Enceladus' surface, which plunges to –328° F (–200° C). Could the geysers' hydrothermal source serve as a moist refuge for saturnian extremophiles? NASA/JPL/SSI

But Ferroplasma acidarmanus likes it there just fine. This microbe is a member of the Archea, Earth's earliest forms of life. It grows best at an acidic pH of 1 and a temperature of 240° F (115° C). For comparison, consider that lime juice has a pH of 2, similar to vinegar. But F. acidarmanus can even tolerate a pH of 0 — battery acid. It does this by using protons in an electrical balancing act that fends off the worst effects of acidity within the cell.

Some organisms have adapted to multiple environmental extremes. Meet Bacillus infernus, the "bacillus from hell," which withstands a combination of great heat, pressure, and acidity. This hardy microbe turned up in a deep-drilling project in Virginia. B. infernus lives in rock several miles underground, where the pressure is hundreds of times greater than on Earth's surface.

So far below the surface, an organism is detached from the conventional biosphere. It exists independently of the Sun's rays, doesn't use photosynthesis, and doesn't consume the organic material from other formerly living organisms. Life is hard when you live in rock, so B. infernus divides only about once every thousand years.

Chris Impey *is a University Distinguished Professor at the University of Arizona's Steward Observatory. He is the author of a book about astrobiology,* The Living Cosmos *(Random House, 2007).*

Now meet Deinococcus radiodurans, "Conan the Bacterium," which can tolerate radiation thousands of times more intense than a dose that would kill a human. Inspectors found this tough customer in a can of meat that had been sterilized with radiation but spoiled anyway.

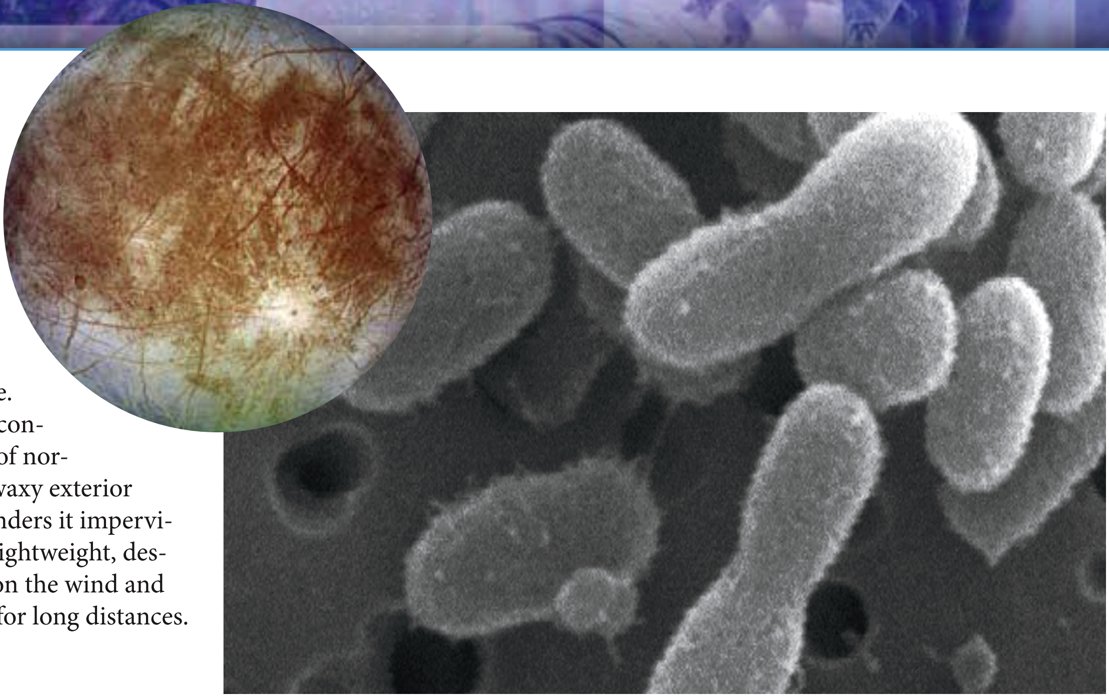
Feisty D. radiodurans has the amazing ability to repair radiation damage to its DNA, usually within 24 hours. It keeps five stacked copies of its genome and protects itself by forming a tough outer layer of fatty lipid particles that can survive both the vacuum of space and punishing ultraviolet radiation. The microbe renders poisonous solvents and heavy metals harmless, while shrugging off intense radiation. The Department of Energy is using Conan to help clean up 3,000 polluted Superfund sites around the country.

Microbial Godzilla

Last, consider a creature that's like Godzilla compared to a normal extremophile. The remarkable tardigrade is no bigger than the dot above this *i*, yet it occupies a major branch in the tree of life. Often called "water bears," tardigrades have five body segments, four pairs of clawed legs, a single gonad, a multilobed brain, digestive and nervous systems, and separate sexes. Researchers have identified more than 750 distinct species.

Only a mother could love these intimidating arthropods, but their amazing adaptability deserves our respect. Tardigrades live in all climate zones. They handle temperatures from –328° F to 300° F (–200°C to 150°C). Pressures from vacuum to 1,000 atmospheres don't trouble them. And move over Conan, water bears can absorb a thousand times the radiation that would kill you or me.

Water bears survive adversity by going into cryptobiosis, a truly deathlike state where metabolism plunges to 0.01 percent of its normal rate, or is undetectable. The organism's water content falls to 1 percent of normal. It forms a hard, waxy exterior called a tun, which renders it impervious to the elements. Lightweight, dessicated tuns disperse on the wind and hitchhike on animals for long distances.



The microorganism Chryseobacterium greenlandensis revived itself after lying dormant for 120,000 years in glacial ice at a depth of nearly 2 miles (3.2 kilometers). The existence of such a cold-hardened bacterium on Earth raises hopes of finding life in the solar system's frigid frontiers. One place that may harbor extraterrestrial extremophiles is the liquid ocean beneath the icy crust of Jupiter's moon Europa (inset). Jennifer Loveland-Curtze (PSU); Inset: NASA/JPL/DLR

Alien extremists

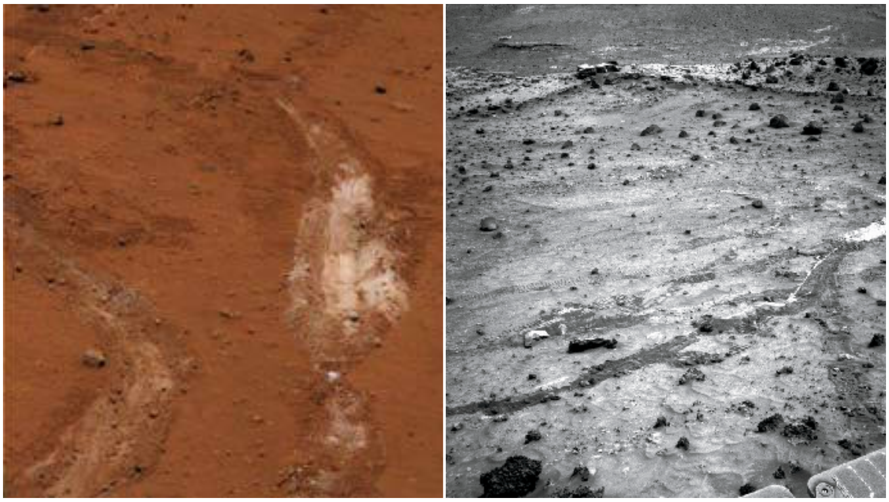
Earth must shape our expectations for finding biology elsewhere in the universe. Extremophiles challenge fundamental assumptions about what life is and what normal is.

The term extremophile is anthropocentric. Their environments seem extreme only to us. To an extremophile, they're normal. The range of adaptation of terrestrial life makes it more plausible that microbial life could exist in the martian permafrost, or in the frigid oceans of Europa, or in a half dozen other harsh and exotic environments in the outer solar system. Microbes might have hitchhiked on meteoritic debris between planets and moons. Extremophiles may even give us tips for our own travel in space, because cryptobiosis (suspended animation) is likely to be a requirement if we're ever to travel to the stars.

At the very least, extremophiles expand the definition of a star's habitable zone far beyond the slender range of distances at which liquid water can exist on a planet's surface. Extremophiles show that life on Earth is like a liquid that has filled the full "shape" of the environmental conditions. On planets beyond the solar system, we have every reason to believe that microbial life will adapt to local conditions and so may be weirder than anything we've seen on Earth.

Heat is available in the crust of any large planet or any moon gravitationally flexed by the planet it orbits. If life can thrive under a planet's crust or deep in its oceans, it may not need an atmosphere. If life can use hydrogen as a nutrient and get its energy from infrared radiation, it may be happy with any kind of host star — or may not need a star at all!

Across the cosmos, planets and moons covered by a web of extremophiles may be the norm. It's hard to feel kinship with Bacillus infernus, but the fecundity of the universe and the prospect of microbial life on millions of planets beyond the solar system are thrilling developments in astronomy.



Skid marks from the Mars Exploration Rover Spirit exposed a patch of bright-toned sand rich in the mineral silica. The marks lie within a larger area, called Home Plate (right), that may be the remnant of a volcanic hydrothermal system or volcanic vent. Such environments could have hosted colonies of martian extremophile bacteria. NASA/JPL/Cornell

Learn more about extremophiles on Earth at www.Astronomy.com/toc.

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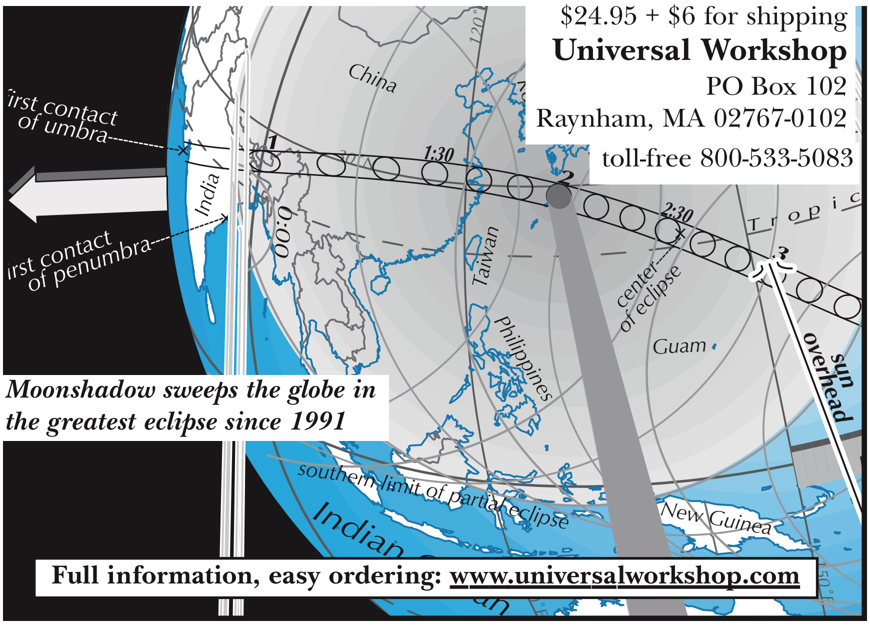
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Ask Astro

Astronomy's experts from around the globe answer your cosmic questions.

Why doesn't the 1987 supernova count?

Q: Astronomers say our galaxy hasn't seen a supernova in 400 years. Why don't they count the 1987 supernova? — **Judy Pearce,** Belton, Texas

A: The 1987 supernova (SN 1987A) occurred in the Large Magellanic Cloud (LMC), not the Milky Way. The LMC is a smaller satellite of the Milky Way, but astronomers still consider it to be outside our galaxy. The 400-year figure refers to visual observations of supernovae in the Milky Way Galaxy itself.

Astronomers know other supernovae have occurred in the Milky Way since 1604, when Johannes Kepler studied one. But once scientists account for all known remnants and their ages, the Milky Way's supernova rate still seems lower than that of other spiral galaxies. Astronomers suspect they've either misidentified or overlooked some remnants.

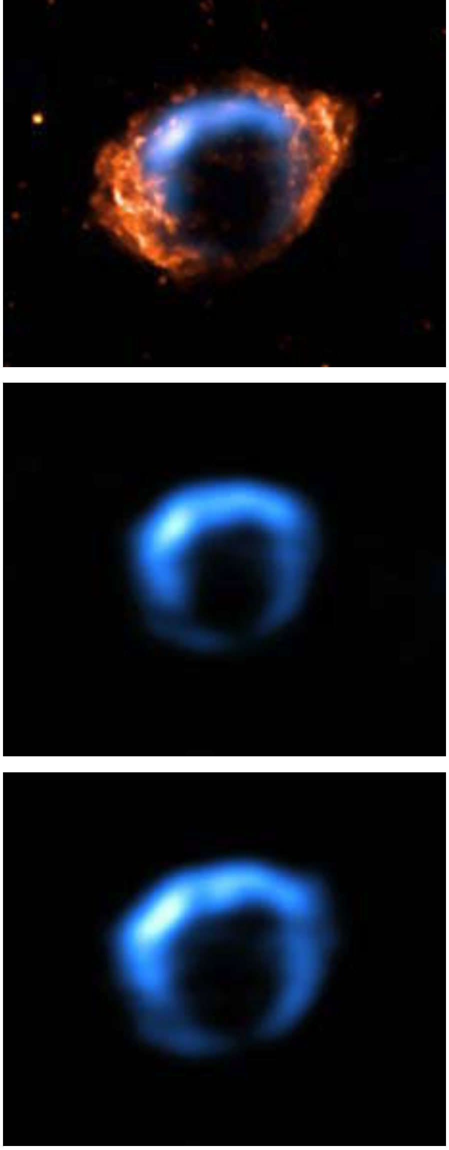
Just because we don't see supernovae doesn't mean they aren't occurring. Dust in the galaxy's plane prevents a lot of light from reaching us. Infrared and radio wavelengths can penetrate this dust and reveal new remnants. Then, astronomers can watch how fast the remnants expand and figure out how old they are.

Supernova remnant Cassiopeia A, the brightest celestial radio source beyond the solar system, is only about 300 years old. The only recorded sighting was by John Flamsteed August 16, 1680, when he cataloged a star in the remnant's position.

The Milky Way's youngest known supernova remnant is a radio source called G1.9+0.3. The remnant, which lies 26,000 light-years away, is only about 140 years old. This means the supernova's light swept over Earth about 140 years ago, but it took 26,000 years for light from the blast to reach us.

Radio astronomers using the Very Large Array in New Mexico found that G1.9+0.3 grew by 16 percent between 1985 and 2008. That corresponds to expansion velocity of 30 million mph (48 million km/h), or about 5 percent of light-speed. Because it's so young, G1.9+0.3 is still getting hotter and brightening at radio frequencies.

Supernova remnants usually glow, thanks to interstellar gas heated by the explosion's expanding shock wave. But astronomers say most of the energy G1.9+0.3 radiates arises from the debris of the exploded star. — **Francis Reddy,** senior editor



Light from the Milky Way's most recent supernova first reached Earth 140 years ago. The remnant, dubbed G1.9+0.3, lies near the galactic center, 26,000 light-years away. Top: This view of G1.9+0.3 merges 1985 radio data (blue) from the Very Large Array (VLA) with 2007 X-ray data from NASA's Chandra X-ray Observatory (orange). Middle and bottom: VLA images of G1.9+0.3 in 1985 and 2008 show the remnant's dramatic expansion. Top: NASA/CXC/NCSU/S. Reynolds et al.; middle & bottom: NSF/NRAO/VLA/Cambridge/D. Green et al.

INFERRED OR INTERFEROMETRIC?

Q: Astronomers have estimated star diameters from their colors and brightnesses, but modern interferometers can measure them directly. How do the two methods compare? — **Dale E. Adams,** Wichita Falls, Texas

A: The two methods complement each other. Inferring star diameters from their relationships to color and luminosity is valuable in a general sense. This method provides reliable diameters for representative stars of given colors, spectral types, and luminosity classes. Astronomers have calibrated the results independently using other methods. These include lunar occultations, where the Moon passes in front of a target star, and observations using interferometers, instruments that combine multiple telescope views into a single, sharper image.

Interferometers can, however, accurately measure a given star's diameter to determine the effects of factors like metallicity (the relative abundance of heavy elements compared to hydrogen), temperature, rotational speed, and age.

Color/luminosity relations average out these parameters, which shows astronomers the broader picture. On the other hand, we can compare interferometer measurements to the detailed predictions of theories of stellar structure and evolution. For example, interferometer measurements of the diameters of M-type dwarfs reveal a discrepancy: A star's metal content has a greater effect on its diameter than theory predicts.

Ever wonder why Mars is red? Find out at www.astronomy.com/toc.

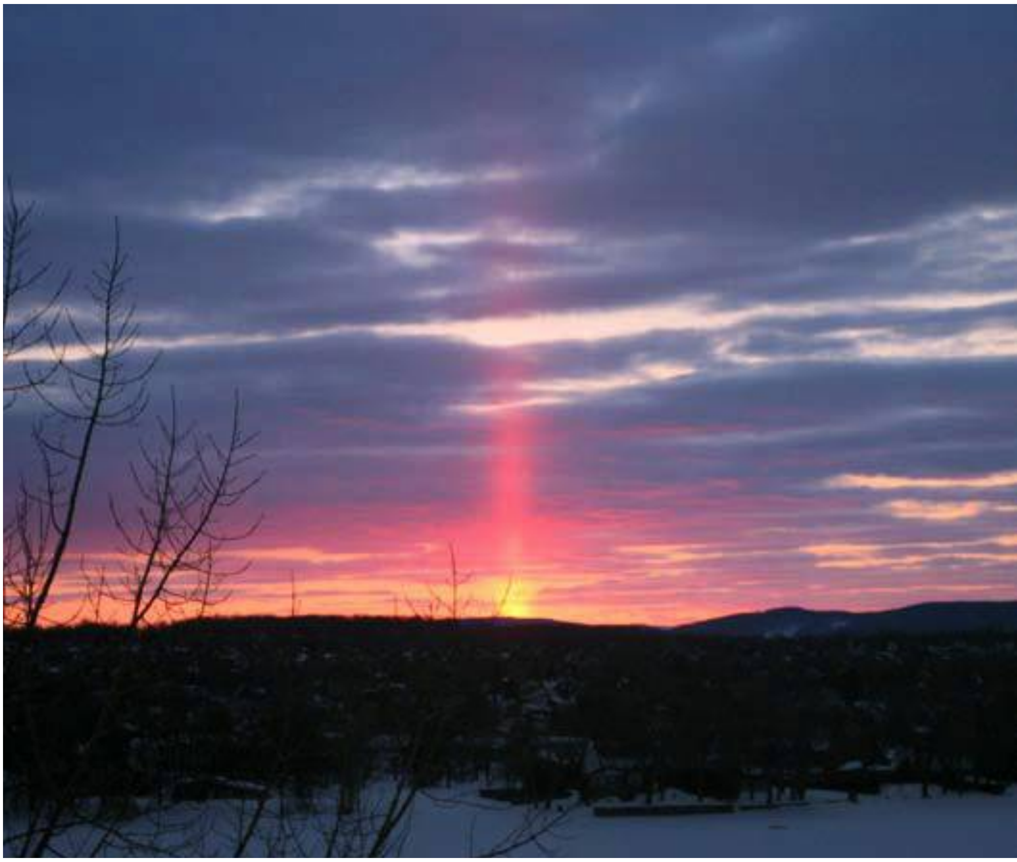
KEY WORDS

interferometer
An instrument that combines light from multiple telescopes to obtain sharper views of celestial objects.

supernova
The catastrophic explosion of a star, which blows off most of its mass. The explosion brightens the star.

lunar occultation
An event in which the Moon blocks the light from a star or planet.

M-type dwarf
A small, cool, red, low-mass star with a spectrum rich in molecular lines, such as Proxima Centauri or Barnard's star; a red dwarf.



A Sun pillar created the sword-like apparition in this photo as the Sun set over Montreal March 16. Plate-like, hexagonal ice crystals reflect the Sun's light to create the glow. Ewa Babarowski

Modern interferometers can resolve diameters for a great variety of different stars. So, for the first time, astronomers have the ability to measure the sizes of thousands of stars. This will improve the calibration of color/luminosity relations and make our theories confront reality. — **Harold A. McAlister,** Center for High Angular Resolution Astronomy, Georgia State University, Atlanta

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SHUTTLE SPIN

Q: Why does a space shuttle rotate shortly after launch? — **Kelly Berger,** Weeksbury, Kentucky

A: First, a shuttle must launch to achieve the desired orbit orientation. Nowadays, this is the orbital plane of the International Space Station (ISS), which is inclined 51.6° to Earth's equator. Because the launch pad can't pivot to the needed angle before liftoff, a shuttle must rotate after launch to adjust. Then the vehicle, which initially moves slightly faster than ISS because it starts off in a lower orbit, can "catch up" to the station and dock with it.

Second, about a minute after liftoff, all atmospheric forces on the vehicle reach their peaks. **Rotating a shuttle right after launch puts the vehicle into a position that helps reduce stress on the orbiter, especially on the wings and tail.**

Finally, the roll maneuver enables a shuttle's pilot to see the horizon. This provides an important reference in the event controllers need to abort a mission during launch. — **Bill Cooke,** NASA's Marshall Space Flight Center, Huntsville, Alabama

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GALAXY CRASH

Q: Could a dwarf galaxy merging with the Milky Way have triggered the solar system's formation? — **Charles J. Waltermann,** Richmond, Indiana

A: It's unlikely. Such mergers occur at speeds measured in hundreds of thousands of miles per hour. In contrast, the Sun is moving at only 38,000 mph (61,200 km/h) relative to the average motion of the Milky Way's stars. This is no faster than random motions of the galaxy's interstellar gas clouds. If the solar system were related directly to a galaxy merger, it would probably be moving faster than random background motions.

Moreover, the Sun's motions are similar to those of native gas clouds. This suggests the solar system formed from gas within the Milky Way. — **Abraham Loeb,** Harvard University, Cambridge, Massachusetts

ICY OPTICS

Q: As the Sun set one evening, I observed a sword-like column of light pointing straight up from the horizon. What was it? — **Ewa Babarowski,** Pierrefonds, Quebec

A: What you saw is called a Sun pillar. This vertical shaft of light extends upward from the Sun. It's usually observed at sunrise or sunset. Sun pillars form when sunlight reflects off the surfaces of falling ice crystals associated with thin, high-level clouds, such as cirrostratus.

These ice crystals are flat plates with six sides. They fall with a horizontal orientation, gently rocking from side to side on their way down. When the Sun is low on the horizon, an area of brightness appears in the sky above (or below) the Sun as the tipped ice-crystal surfaces reflect its light. — **Francis Reddy,** senior editor

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI, 53187.** Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Imaging the old and new

Astroimaging over ancient Greece

A Mediterranean astrophotographer frames celestial portraits with millennia-old ruins.

text and images by Anthony Ayiomamitis

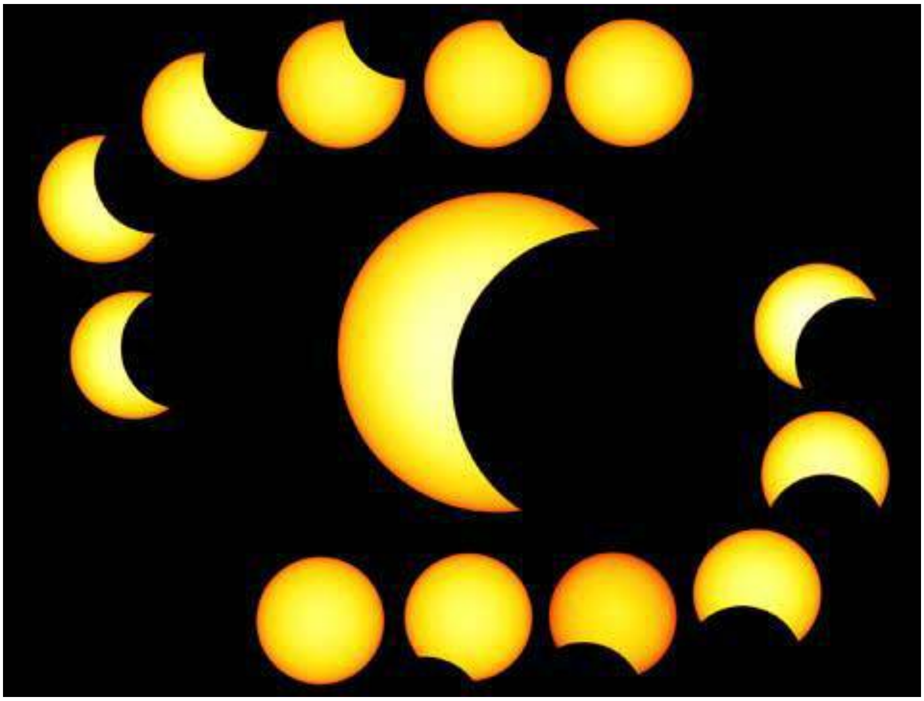
Most amateur astronomers ask only one question: "Will it be clear tonight?" My considerations, as an astroimager, go a bit deeper. For example, clear weather is essential, but I also want to know if the seeing (a measure of the atmosphere's steadiness) will be good. Also, is my equipment working? And, finally, how can I make my planned shots special? Because I live in Greece, a country with thousands of years of history reflected in ancient ruins, I often incorporate them into my images.

A humble start

After living my first 10 years in Greece, my family moved to Toronto, Canada. My first "exposure" to photography came through my high school physics teacher, Mr. Randy Saylor, when he started the school's camera club at Bloor Collegiate Institute there.

Little did I know at the time that 2 decades later — thanks to early retirement and a return to Greece in May 1999 — I would find myself immersed in astronomy and astrophotography. I now pursue billion-year-old photons in the company of Greek temples "only" thousands of years old, but no less interesting.

I cherish difficult and eccentric objects as well as more traditional targets. Imaging that involves celestial dynamics (how sky objects move) is of particular interest because it helps me understand and visualize the universe at work. At the same time, I like modern imaging challenges including quasars and blazars, gravitational lensing, dwarfs, hypervelocity stars, differential photometry, and exoplanet transits. I use evenings with limited windows of opportunity due to a rising Moon or other less than ideal conditions for these diversions.



∧ A partial solar eclipse occurred October 3, 2005. The author shot 1/500-second exposures through a Baader ND-5 solar filter covering the objective of his 6.4-inch Astro-Physics StarFire EDF apochromatic refractor. He combined the individual exposures into one image.

> Anthony Ayiomamitis stands next to his 6.4-inch Astro-Physics StarFire EDF apochromatic refractor. This instrument is one of three high-quality telescopes he images with.

Photometry, for example, does not require good seeing or transparency. Photometry is the technique that measures the radiation we receive from celestial objects. I concentrate on visible wavelengths. Even on a night when imaging is impossible, I can produce a lightcurve of an eclipsing binary star.

Through my photography, I often combine the archaeological grounds

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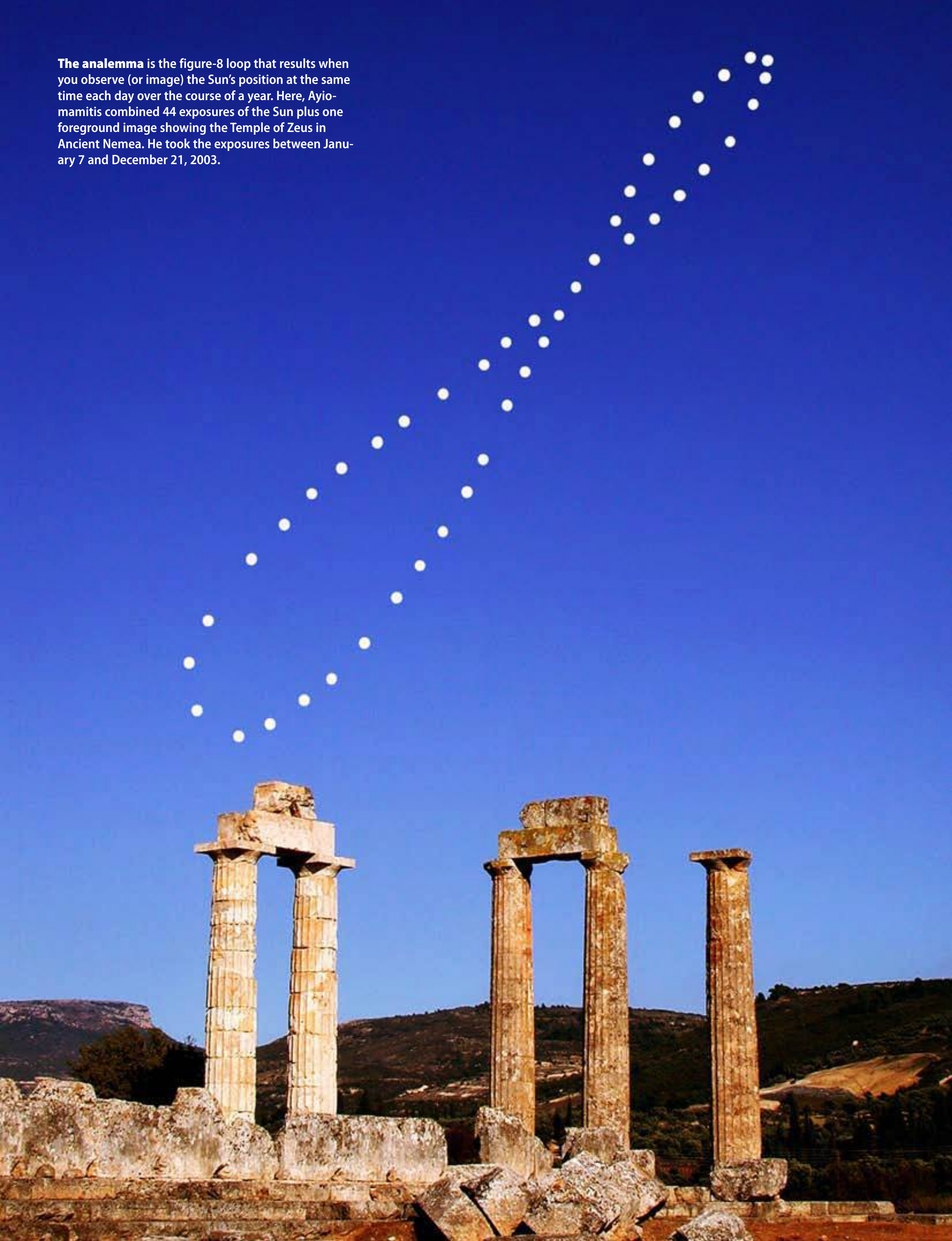
Anthony Ayiomamitis *frequently contributes images to* Astronomy.



The analemma is the figure-8 loop that results when you observe (or image) the Sun's position at the same time each day over the course of a year. Here, Ayiomamitis combined 44 exposures of the Sun plus one foreground image showing the Temple of Zeus in Ancient Nemea. He took the exposures between January 7 and December 21, 2003.

from the classical age of ancient Greece with astronomical events. One of my themes highlights the rising and setting Sun and Moon against notable ancient temples. I have done analemma photography since 2001. (The analemma is the figure-8 pattern the Sun makes throughout the year, if seen [or imaged] at the same time each day.)

Tools of the trade

For imaging, my pride and joy are my 6.4-inch Astro-Physics 160mm f/7.5 air-spaced triplet refractor and my 12-inch Astro-Physics f/12.5 Maksutov-Cassegrain reflector. Both ride on dedicated Astro-Physics AP1200 GTO German equatorial mounts. Such premium equipment makes my precious time under the starry sky proceed efficiently. These telescopes also allow me to image objects that normally would be beyond reach.

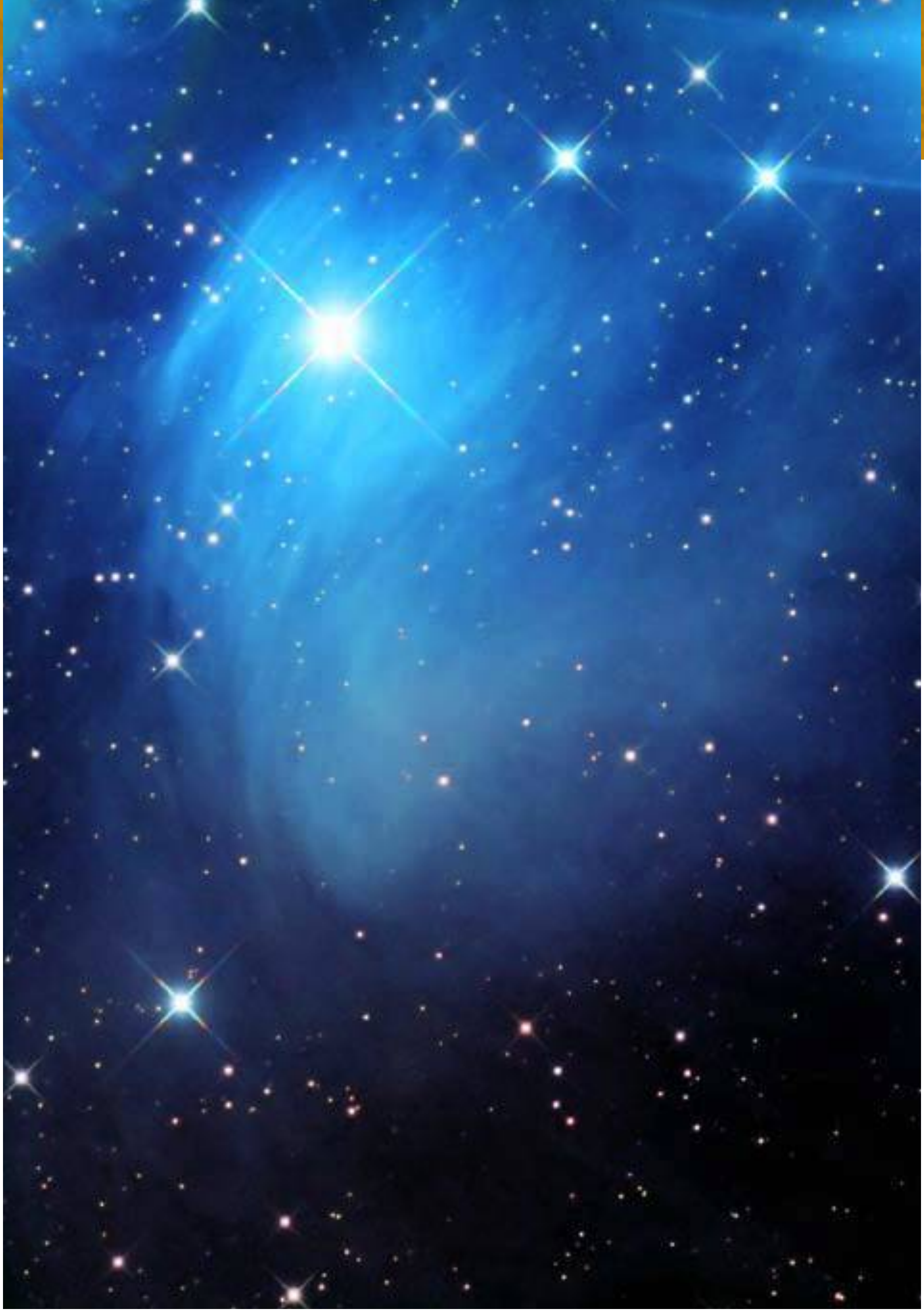
Also forming a part of my arsenal is a Takahashi FSQ106 f/5 four-element refractor. I mounted this impressive little scope on an Astro-Physics Mach1 GTO equatorial mount. I use this setup for wide-field imaging, as well as when I'm chasing lunar and solar eclipses.

The camera I choose depends on my target. My DMK firewire video camera is ideal for high-resolution imaging of solar system objects. I use my Canon EOS 300D and 350XT for eclipses, occultations, and conjunctions. Finally, I use my SBIG ST-2000XM and STL-11000XM CCD cameras for imaging the deep sky in true-color (RGB) and narrowband (Hydrogen-alpha and others) ranges.

Sky quality counts

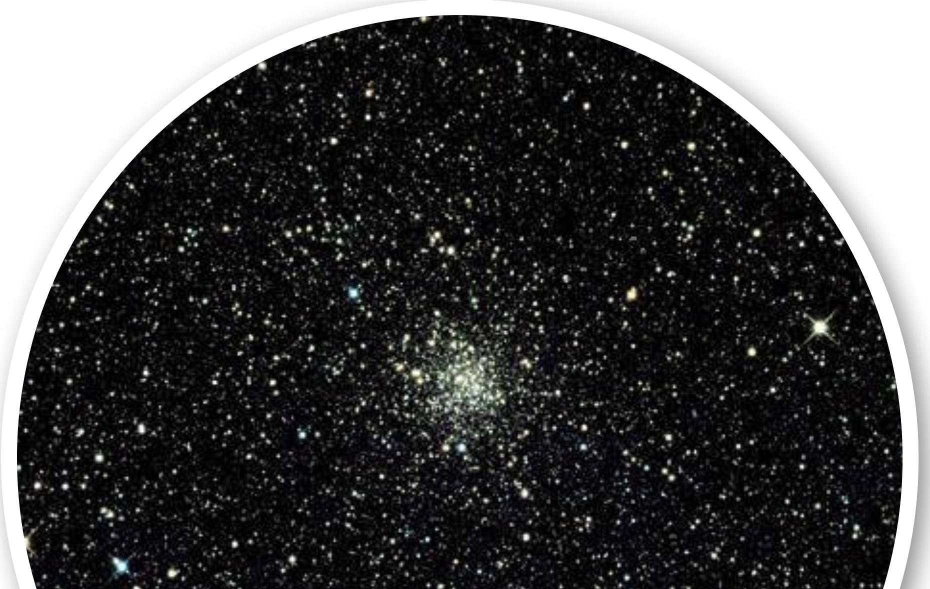
Greece has some of the darkest skies in Europe. I take most of my images at my cottage-villa on the northeast outskirts of Athens, a 26.5-mile (43 kilometers) drive from home. There, skies easily reach a limiting visual magnitude of 4.5 and exceed 5.0 during winters. The constellation Ursa Minor is usually visible in its entirety without averted vision, the Milky Way is a beautiful site year-round, and I can see many bright deep-sky objects without optical aid.

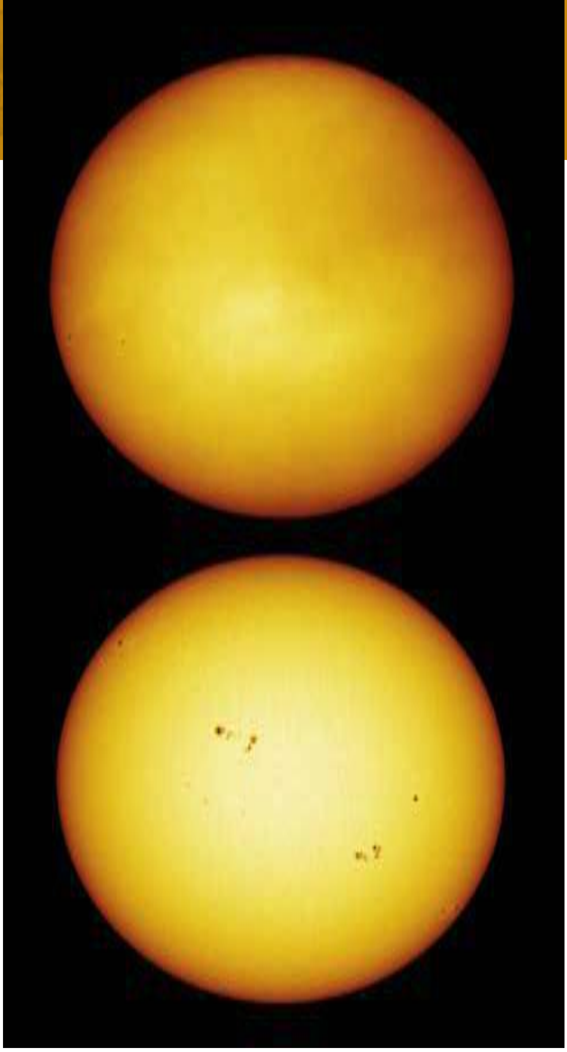
Continued on page 69



∧ **The Merope Nebula** (NGC 1435) is a wispy reflection nebula surrounding the 4th-magnitude star Merope (23 Tauri) in the Pleiades (M45). It's a challenge to see through a 6-inch or smaller telescope.

∨ **Globular cluster M71** lies off the beaten path in Sagitta. Ayiomamitis often shoots less-than-spectacular celestial objects, like open star clusters, that other astroimagers neglect.

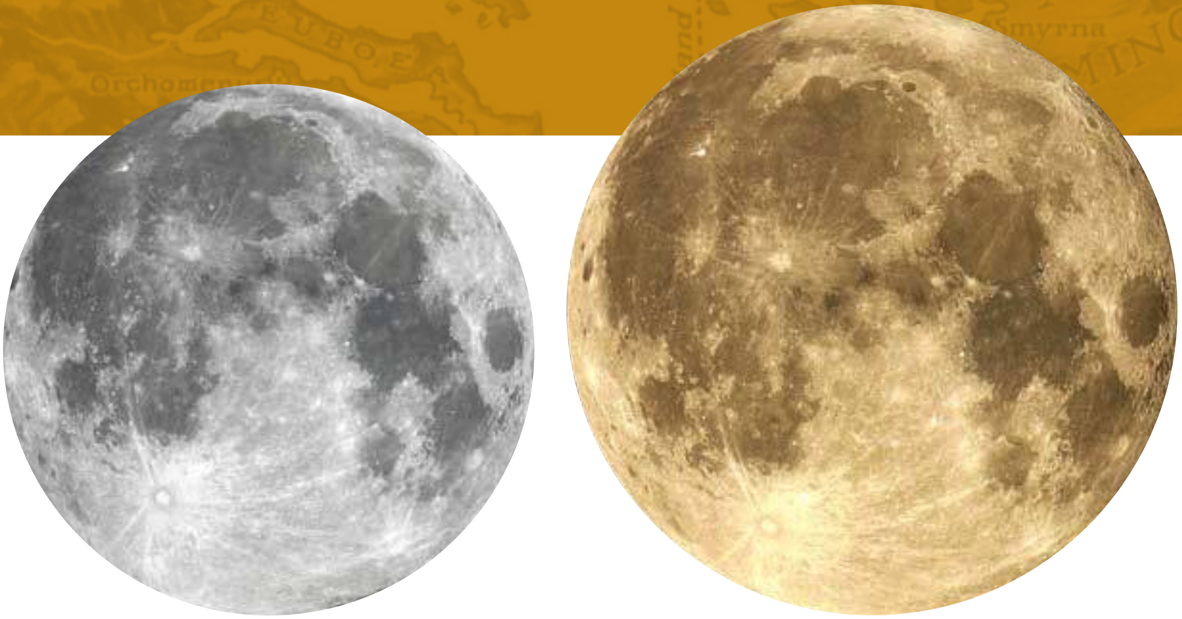




To show perihelion and aphelion — those times when Earth is farthest from and nearest to the Sun, respectively — the author shot our daytime star 6 months apart, on January 4 (top) and July 5, 2005. He took both images through a Canon EOS 300D digital SLR attached to his 2.7-inch Tele Vue Pronto apochromatic refractor.

Reflection nebula NGC 7129 in Cepheus lies 3,000 light-years away. Astronomers think this star-forming region's stars are young (only about a million years old). The author's image shows many colorful stars in this region.

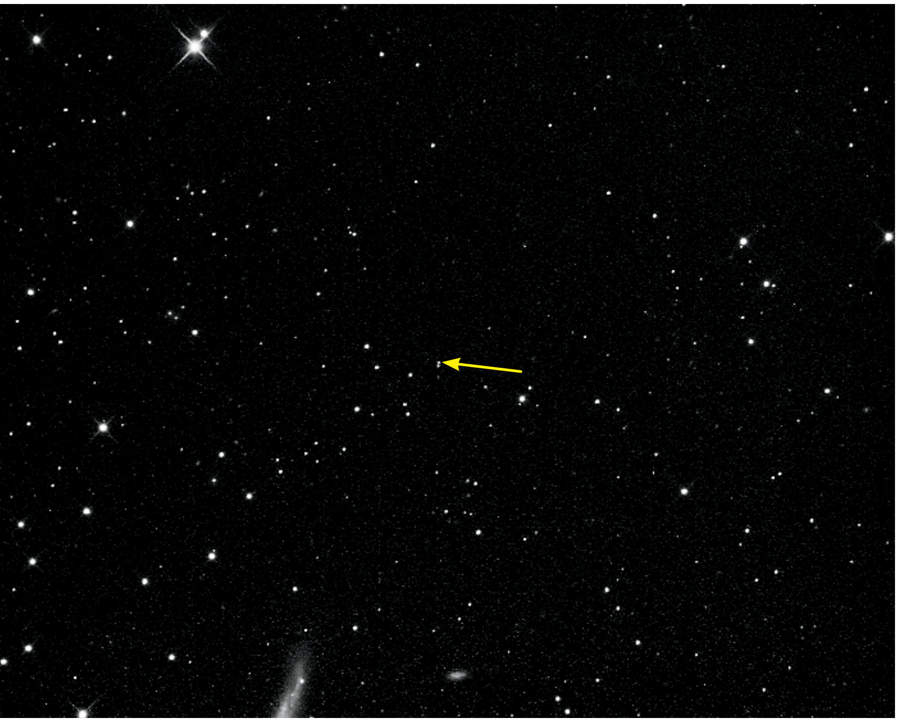
The eclipsed Moon, Saturn (right of the Moon), and Leo's brightest star, Regulus (below the Moon), appear above the Temple of Poseidon in Athens, Greece, February 21, 2008. Ayiomamitis used his car's headlights to illuminate the temple during the 8-second exposure.



Apogee

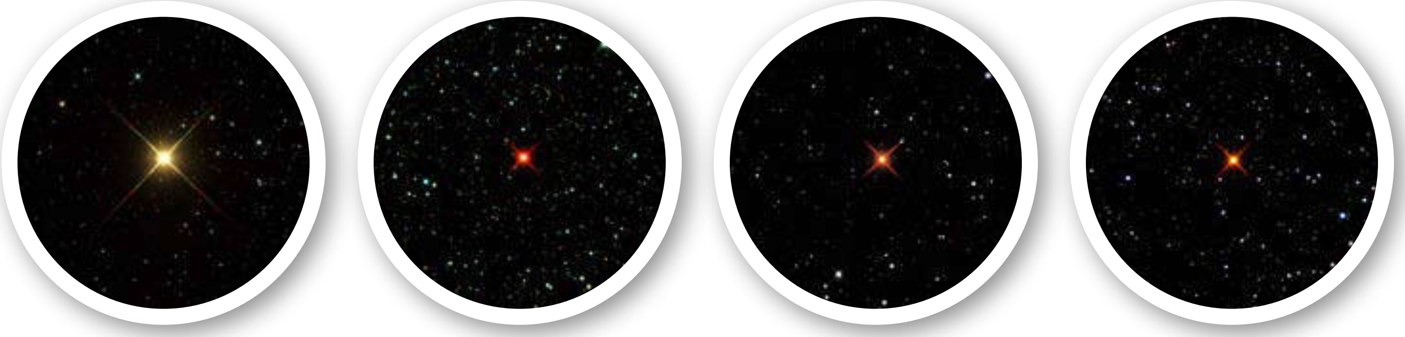
Perigee

Apogee (left) and perigee describe points in the Moon's orbit where it lies farthest from and nearest to Earth, respectively. Unlike the small change in the Sun's diameter at its extremes, the Moon shows a 14 percent change in size between apogee and perigee. The author took the left image February 13, 2006, and the right image July 21, 2005.

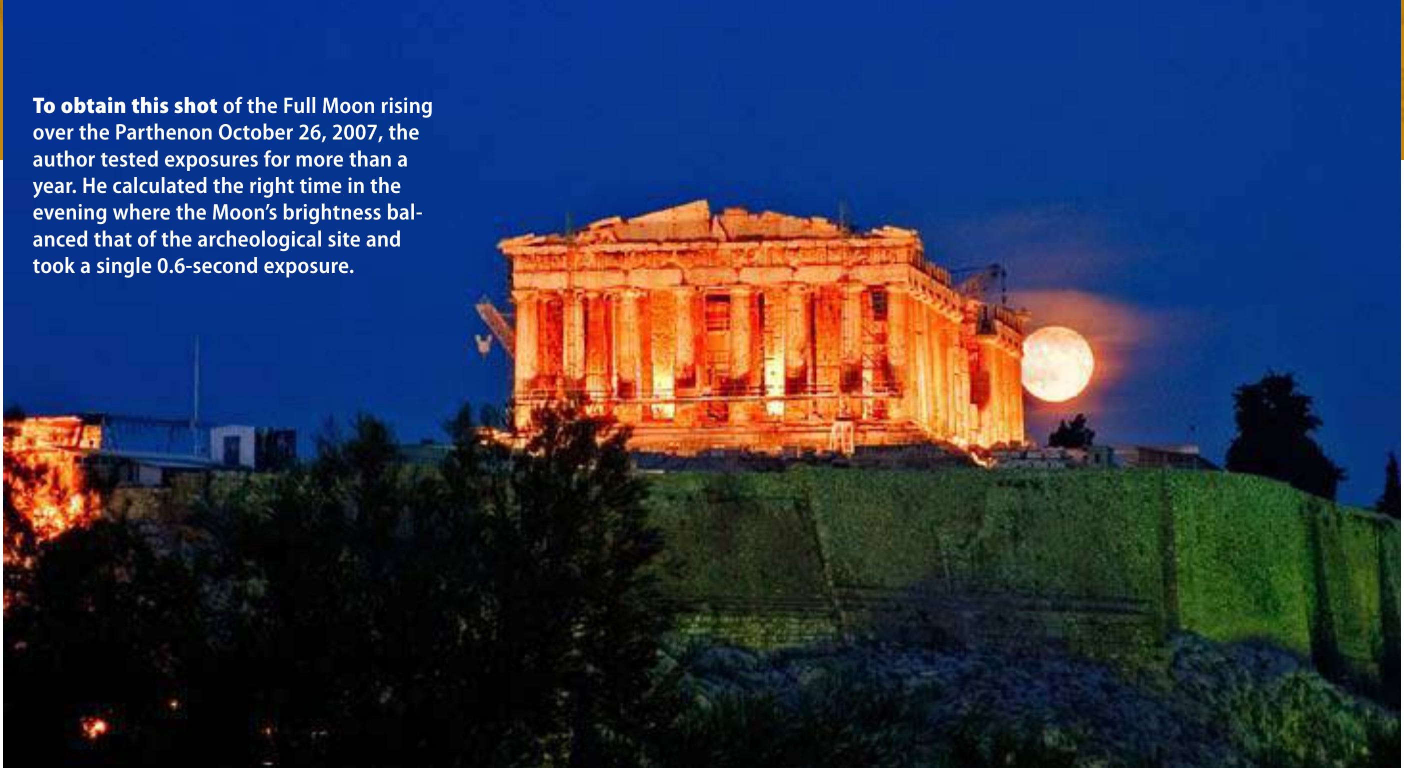


The author enjoys a challenge, so he sometimes photographs quasars. For this image, he pointed his telescope at Boötes and shot quasar PKS 1354+19 (arrow). At magnitude 16, it represents a challenging target. It lies 9.9 billion light-years away.

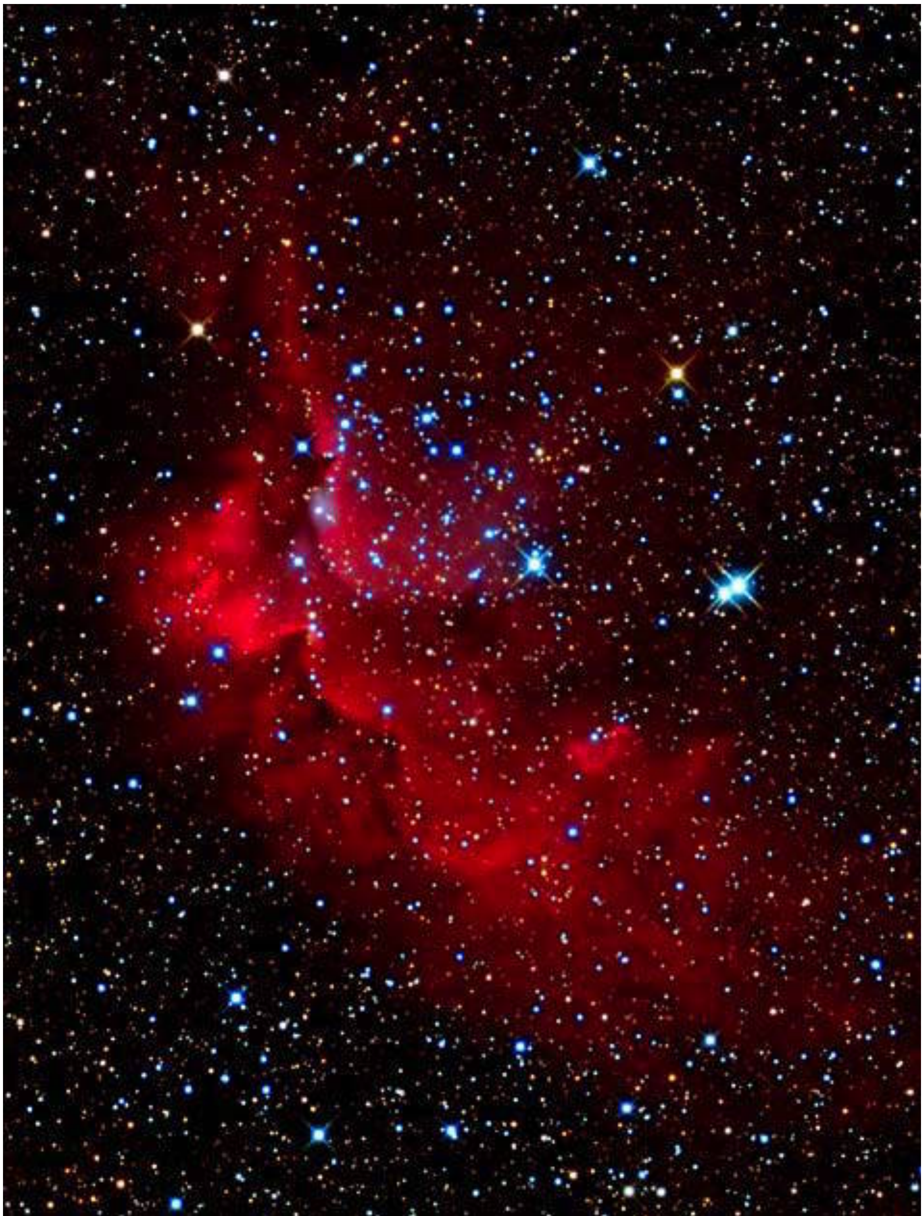
One half of the Double Cluster (NGC 884 — the other is NGC 869) in Perseus demonstrates the author's skill at capturing open star clusters. The differences in brightnesses and colors give this object a 3-D appearance.



This set of red stars shows a small part of one of the author's recent imaging projects — to photograph examples of carbon stars, variable stars that are the reddest in the sky. Left to right, the stars are Herschel's Garnet Star (Mu [μ] Cephei), V Cygni, T Lyrae, and AW Cygni.



To obtain this shot of the Full Moon rising over the Parthenon October 26, 2007, the author tested exposures for more than a year. He calculated the right time in the evening where the Moon's brightness balanced that of the archeological site and took a single 0.6-second exposure.



> **Open cluster NGC 7380** in Cepheus intertwines with a reddish emission nebula. The author shot, and then combined, 35 ten-minute exposures of this star-forming region through his 6.2-inch Astro-Physics 160mm refractor.

Continued from page 66

When in pursuit of even darker skies, I head to the top of Mount Kithaironas at an elevation of 4,690 feet (1,430 meters). This site lies about 55 miles (90 km) northwest of Athens where the sky has a limiting magnitude of 6.0 and where I often find myself above low-level clouds.

During summers, my favorite location is Mount Parnon, a 2½-hour drive southwest of Athens. Here, skies reach a magnitude of at least 6.5, and the Milky Way is one rich cloud covering the sky from the northeast to the southwest.

The locations I mentioned have nice weather from early spring to late fall. In order to combat the shorter clear summer nights and the longer but problematic winter nights, I exploit every available minute by having three scopes simultaneously imaging the countless wonders of the overhead sky.

I've come a long way from high school camera club meetings. And, although I've taken lots of pictures, I still have many more celestial wonders I want to image.

See more of Anthony Ayiomamitis' images at www.Astronomy.com/toc.

Meade's LX90-ACF eliminates coma

High portability, easy setup, and high-quality optics make this scope a winner.

by Mark M. Marcotte

Meade's LX90-ACF features an optical design that eliminates the optical defect coma.

The tried-and-true 8-inch telescope from Meade has taken another step forward with the latest version, the LX90-ACF. "ACF" stands for "Advanced Coma-Free." Coma is an optical defect that distorts off-axis images (those far from the field of view's center).

The LX90-ACF comes equipped with multicoated optics, a GPS receiver, two finder scopes, Level North Technology, and the AutoStar controller with AutoAlign software. Meade's design of this telescope emulates the optical performance of a Ritchey-Chrétien design (which also eliminates coma), but at a fraction of the cost.

Under the starry sky

So does it work? I didn't have a Ritchey-Chrétien telescope for a comparison, but I did use the LX90-ACF and an earlier model LX90 on everything from the Moon to some faint planetary nebulae.

My observing showed the LX90-ACF optics work as advertised. I received clear, coma-free images of stars and galaxies to the edge of the field of view.

Lack of coma was most apparent when I viewed open star clusters. The constellation Auriga offers many of those, such as M36, M38, and especially the magnificent Salt and Pepper Cluster, M37.

Globular clusters also were quite spectacular. M3 in Canes Venatici and the Hercules Cluster (M13) stood out as well-resolved showpieces. The LX90-ACF served up outstanding views of the Moon, Saturn, and Jupiter, too.

Views of double stars were also excellent, with no shifts from the colors I expected to see. Most galaxies and nebulae appeared as they should through this size telescope. And the scope kept its defect-free promise as I looked at multiple galaxies in the same field, such as M81 and M82 in Ursa Major. Observing both galaxies at once meant I had to place each at the edge of the field, and that's when the coma-free optics excelled.

How'd they do that?

To produce a flat, coma-free field similar to the kind provided by a Ritchey-Chrétien telescope, Meade uses a full-aperture aspheric corrector lens in conjunction with a spherical primary mirror. In essence, this creates a two-element optical system that performs like the single hyperbolic primary mirror of the Ritchey-Chrétien telescope design.

Meade mounts the hyperbolic secondary mirror directly on the rear of the corrector lens. This eliminates any image-degrading diffraction spikes that conventional spider vanes can produce on a Ritchey-Chrétien scope.

Meade also uses an oversize primary mirror in its LX90-ACF line, meaning the primary is slightly bigger than the corrector lens. In the case of the 8-inch LX90-ACF, the primary measures 8.25 inches. According to Meade, this oversizing results in 5 to 8 percent more off-axis light reaching the eyepiece. Another

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Mark M. Marcotte *is a retired firefighter who observes and tests equipment from the mostly clear skies near Lubbock, Texas.*

The LX90-ACF includes a computer-controlled fork mount and a sturdy tripod. All photos: *Astronomy*: William Zuback

Specifications

Meade 8-inch LX90-ACF

Focal ratio: f/10
Focal length: 2,000 millimeters
Onboard celestial database: 30,223 objects
Optical tube dimensions: 9.1" x 16.75" (23cm x 42.5cm)
Telescope weight: 33 pounds (15 kg)
Tripod weight: 19 pounds (8.6 kg)
Includes: GPS, AutoStar hand controller, red-dot viewfinder, star diagonal, 8x50 finder scope, 26mm Plössl eyepiece (77x)
Price: $1,999

added benefit of the corrector lens is that the closed-tube design keeps the optics free of dust and moisture.

Meade used the same tripod for the LX90-ACF that it supplies with all of the LX200 series telescopes. The tripod is big and sturdy, with telescoping legs that are easy to extend and retract. Each leg has a lever-type locking handle. This is an improvement over the two-knob system used on earlier tripods. A single heavy-duty threaded rod with a large handle fastens the telescope to the tripod and also braces the legs. It's a good, solid design that works well.

Let the computer drive

Aligning the telescope is just a matter of flipping on a switch. Once you power up the drive, all you need to do is enter the "AutoAlign" command into the AutoStar controller. The GPS will then enter your location and the correct time into the computer, and the drive's Level North Technology module will find north.

The main finder scope is an 8x50 unit with a 5° true field of view. Two sets of three screws allow you to align the finder scope accurately.

Once it knows the directions, the drive points the scope to the first alignment star, waits for you to center the star in the field of view (press "Enter"), and then moves to the second star. Center the second star, hit "Enter" again, and you're ready to observe.

Also available on the AutoStar menu is "High Precision." This feature will allow you to fine-tune your alignment as your observing session progresses.

Meade incorporated the Level North Technology module into the Smart-Finder, another new feature on the LX90-ACF. It is a wide-field, nonmagnifying, red-dot finder that you'll use to initially center the object. It has brightness and blink-time adjustments.

The other finder scope is a competent 8x50 finder with a 5° field of view. It has a six-point mounting system that makes it easy to adjust when you're aligning it prior to observing.

Of course, the workhorse that ties this whole package together is the AutoStar controller. This unit has been a steady performer for Meade for several years. Using it is intuitive and easy. Meade provides a holder for the controller that fits conveniently on the telescope's handle. The accompanying AutoStar Suite disc allows you to download any updates.

AUTOSTAR
MEADE
ENTER
MODE
GO TO
1
2
3
4
5
6
7
8
9
0
?

Meade's AutoStar controller is easy to use, even in the dark. It contains a database of more than 30,000 celestial objects. You won't run out of things to look at for a long time.

COMPUTER CONTROL
AUX
HBX
ON
OFF
12v
AUX

The main panel of the LX90-ACF has an input for Meade's AutoStar handbox controller, two auxiliary outputs to control add-on accessories, and a 12-volt input for an AC adapter.

Grade A all the way

Overall, I found the 8-inch LX90-ACF to be an outstanding performer and a good value. With a limiting magnitude of 14 and a resolution of 0.57", it produced enjoyable images of all types of objects.

It's a great utility telescope that is light enough to be set up by one person and compact enough to tote around in the trunk or backseat of a car. The GPS and Level North Technology make it a snap to align, and the AutoStar controller assures it's simple to operate.

Meade also offers the LX90-ACF with 10-inch and 12-inch apertures. These too seem to be a good value, but because of the extra weight and size, they won't be as mobile as their little brother. It appears Meade found a good combination of cost and performance with this instrument. ◆

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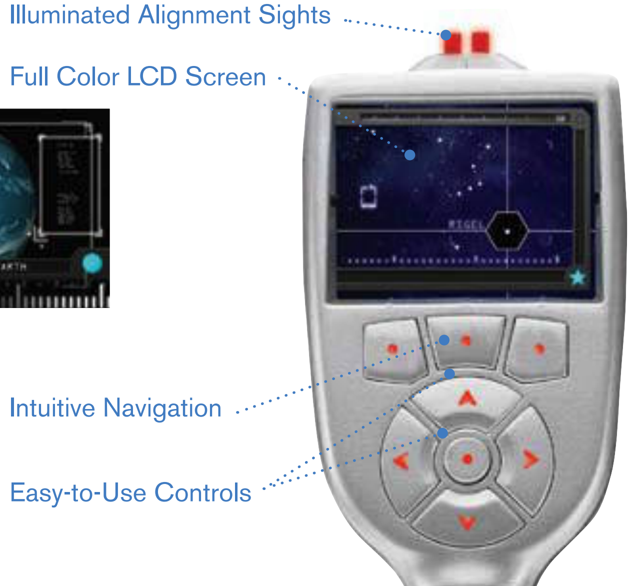
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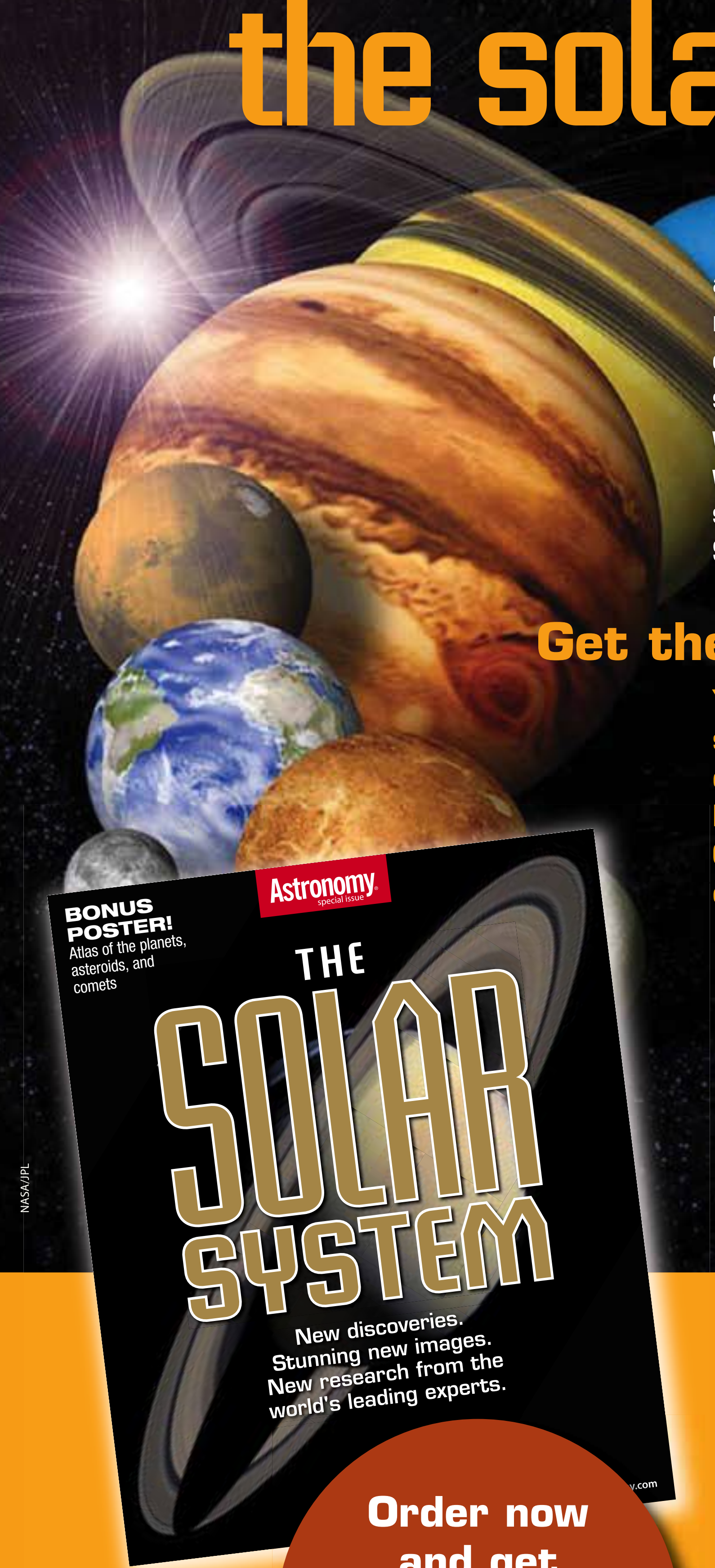

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Observing Basics

by Glenn Chaple

X-rated astronomy

Here are four steps to keep your telescope in excellent shape.

Shame on me for using such a blatantly suggestive title to attract your attention (and shame on you for falling for it)! But be honest — had I suitably titled this month's column "How to care for your telescope," you would have flipped past this page and gone on to Phil Harrington's Binocular Universe column about the variable star Mira.

But Phil would be the first to point out that the proper maintenance of your telescope and accessories is of utmost importance. His book *Star Ware, 4th Edition* devotes an entire section to telescope care.

A well-maintained telescope will last a lifetime — several lifetimes, in fact. Just ask the proud owners of antique refractors constructed during the Civil War era.

Here is a checklist of things you should do to keep your telescope (and astronomy accessories) in peak condition. If you are able to place an "X" next to each item on this telescope/accessory TLC checklist, you may be an X-rated astronomer after all!

1. Put all user's manuals in an accessible place.

A user's manual provides essential details about the use and maintenance of your telescope or accessory, not to mention contact information should you need assistance. Collect all your manuals, place them in sheet protectors, and then clip them into a three-ring binder. Be sure the binder is clearly labeled and placed where you can find it — perhaps on a shelf with your astronomy books.

Can't find a particular manual? Nowadays, many astronomy-related companies offer their user's manuals as online downloads. You could even save the downloads on a disk for use as needed.

Backyard observatories shield telescopes from the elements while allowing users to have easy access to their equipment year-round. They can be as simple as a shed that rolls away to reveal the night sky. Ray Shore

2. Be sure your telescope is properly stored and ready to use.

Keep your telescope fully assembled (you'll use it more often), with dust caps covering the tube and eyepiece holder. For further protection, shield the entire unit with a large plastic bag.

A telescope should be stored in a secure place that's dry, dust-free, and safe from temperature extremes. A backyard observatory would be perfect, if you're one of the fortunate few who live in an open area. Otherwise, house your telescope in a well-ventilated shed, strategically located in a shady area of your yard.

3. Put eyepieces and other accessories in a safe location.

The rules here are similar to those I just outlined for your telescope. Place the protective plastic end caps on your eyepieces and store them in their original boxes, Ziploc bags, or specially designed plastic screw top containers. Another option: Arrange your eyepieces in a specially made foam-lined storage box.

For a fun winter project, make your own eyepiece storage case. Lining a plastic snap-top shoe box with foam pieces (found at a hardware store) would suffice. Years ago, I took a beautiful hinged wooden cigar box and inserted blocks of balsa wood (purchased from a local hobby store) into which I had drilled 1.25-inch holes. The eyepieces fit into the holes, and the box was placed in a cool, dry area of my cellar.

4. Don't clean your optics to excess.

According to my logbooks, I've used my 13-inch reflecting telescope an average of 250 hours each year for the past 28 years. During that time, I've cleaned the primary mirror perhaps a half dozen times. Unlike humans, a telescope doesn't require frequent baths. In fact, overcleaning is a sure way to wear down the delicate optical surfaces of telescopes and eyepieces. The objective mirror of a reflecting telescope can accrue a surprisingly large amount of dust, pollen, and other forms of aerial debris before the image starts to degrade.

When it becomes necessary to clean a telescope mirror, objective lens, or eyepiece, do it cautiously. The aforementioned section of *Star Ware* gives step-by-step instructions for cleaning objective lenses, corrector plates, or mirrors. Web users can find this information, plus hints on cleaning eyepieces, at Lenny Abbey's astronomy web site. Log on to www.labbey.com/Files/clean.txt.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: 2009 — the International Year of Astronomy. Clear skies!

Learn more about sensible housing for telescopes at www.Astronomy.com/toc.

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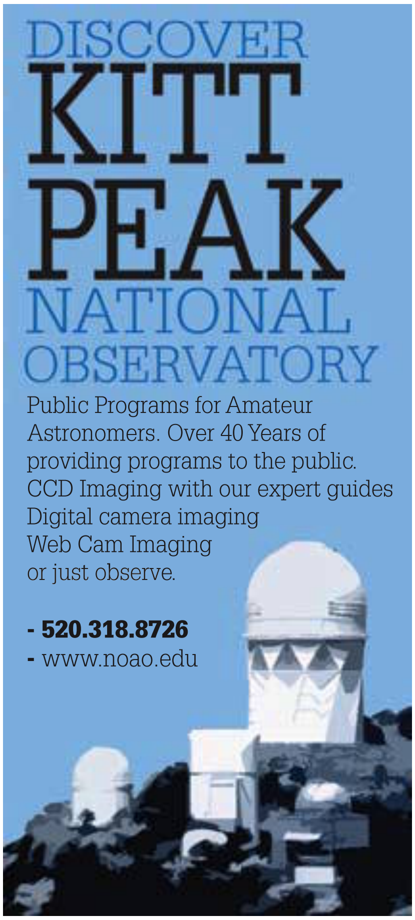

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Binocular Universe

by Phil Harrington

It's a Wonderful Star

The variable star Mira shines brightest in early December.

With the holiday season here, we often look forward to repeating many annual traditions associated with this time of year. One tradition many enjoy is watching the movie *It's a Wonderful Life*, starring Jimmy Stewart and Donna Reed.

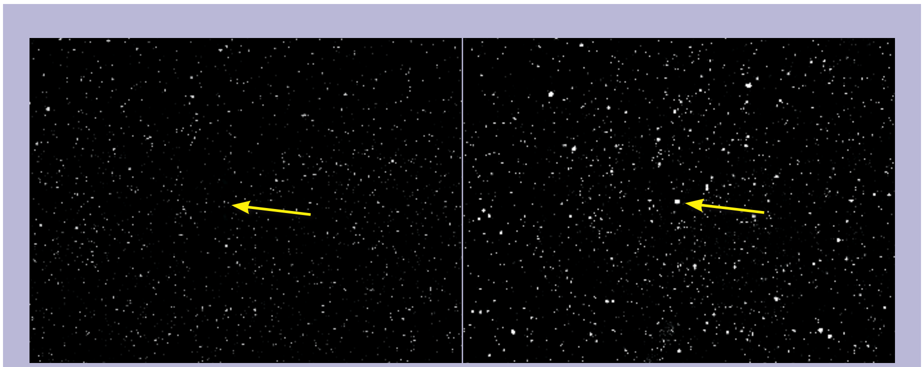
We might use a slight variation on that title to highlight a celestial event occurring this month, as well: It's a Wonderful Star. That's because, early this month, the variable star Mira (Omicron [ο] Ceti) is predicted to reach its maximum brightness. (The name Mira translates as "wonderful," an appellation bestowed on it in 1662 by Johannes Hevelius [1611–1687].) Mira, a red giant, is the brightest and most famous long-period pulsating variable in the sky.

Over the course of 332 days, Mira slowly cycles between a maximum brightness of 3rd magnitude — brighter than any star in its immediate area — to a low of about 10th magnitude, and back again. It's a wonderful star to enjoy through binoculars, especially when near maximum, as its reddish color helps it stand out from the crowd.

Mira was probably at one of these peak performances when Greek astronomer Hipparchus became the first person to spot it in 134 B.C. Its recognition as a variable star, however, is credited to amateur astronomer David Fabricius (1564–1617), who spotted it August 13, 1596, and again February 15, 1609.

There have been instances, when this red giant exceeded 1st magnitude, and others when it never broke the 5th-magnitude barrier. Variable stars can be notoriously unpredictable.

One reason for this inconsistency may be that Mira is the more massive member of a binary star system. Although we can't see it through binoculars, or even through all but the largest telescopes, Mira has a white dwarf companion star. This companion lies some 70 astronomical units (that is, 70 times the average Earth-Sun distance) from Mira and takes about 4 centuries to complete an orbit. As it does, the white dwarf's strong gravitational pull draws material from Mira into a surrounding disk.



Variable star Mira (Omicron [ο] Ceti) has a period of nearly 332 days. During that time, it increases in brightness from 10th magnitude to as bright as 3rd magnitude and then dims again. Mira is expected to reach maximum brightness in early December. John Sanford

Although Mira is usually bright enough to be seen without optical aid when near maximum brightness, finding it can be tough. The problem is that its home constellation, Cetus the Whale, is so faint. To try your luck seeing it, wait until the head of Taurus, known as the Hyades, is up in the sky.

The Hyades' V-shaped pattern points southwest toward a distinctive five-sided asterism that marks the northern end of Cetus. Aim your binoculars its way, and then look just to the south for the 4th-magnitude star Delta (δ) Ceti. Slide about one field farther southwest of Delta, and keep an eye out for a reddish star that marks the right angle in a small triangle of three stars. That red star is Mira.

Estimate Mira's magnitude by comparing it with known reference stars that lie nearby. From your observations, can you determine the exact date when Mira reaches maximum magnitude? Then, as winter progresses, keep an eye on Mira's behavior, making a magnitude estimate every week or so. It should remain visible through binoculars until it is lost in the glare of twilight in late March.

Besides Mira, we have a special guest passing through nearby Pisces the Fishes this month. Throughout December, the asteroid Vesta traces a semicircular path just to the east-northeast of 5th-magnitude Alrisha (Alpha [α] Piscium). As 2008 fades, so will Vesta, dropping from about magnitude 7 on December 1 to about magnitude 7.5 by year's end (see "Locating asteroids," page 51).

Speaking of year's end, I hope that you have enjoyed the wealth of sky events and objects that have been visible through our binoculars over the past 12 months. Have you seen something that you'd like to bring to the attention of others? Drop me a line at phil@philharrington.net and tell me about it.

In the meantime, until we meet again next year, always remember that two eyes are better than one.

Learn how to estimate Mira's magnitude at www.Astronomy.com/toc.

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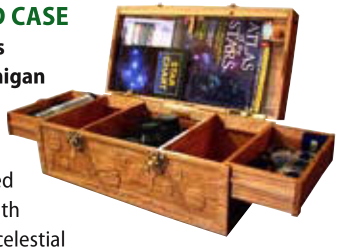

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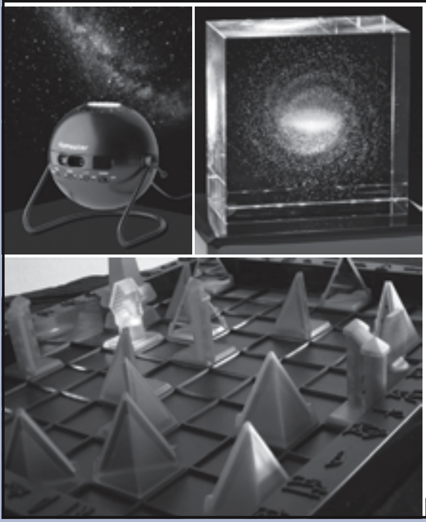
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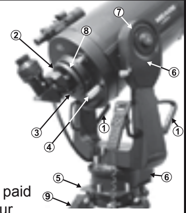

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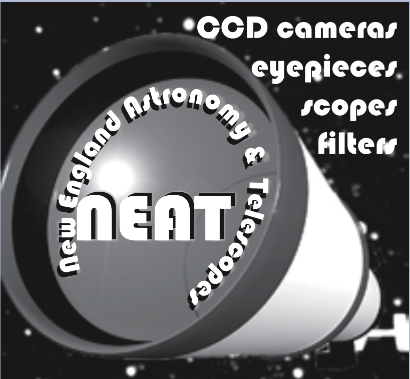

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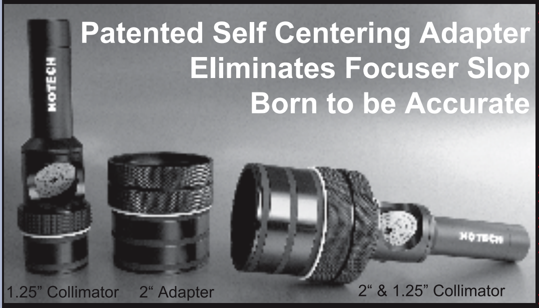

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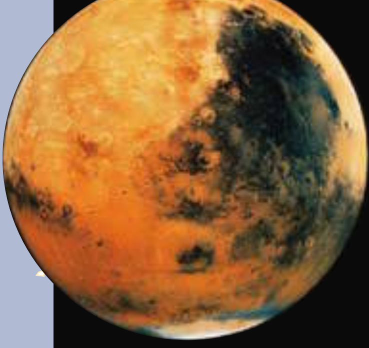

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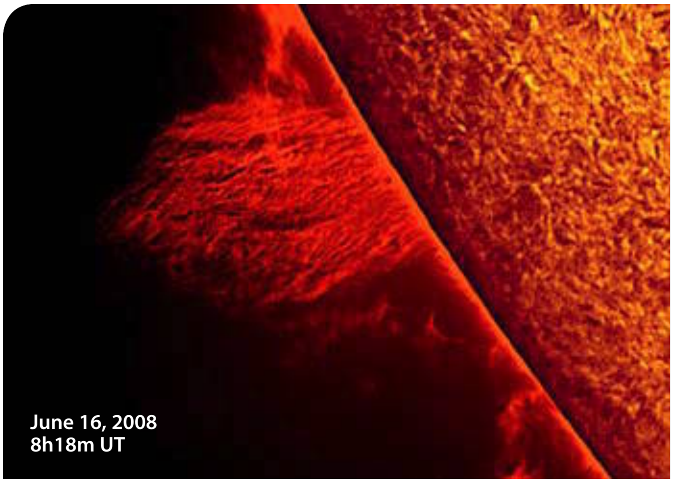
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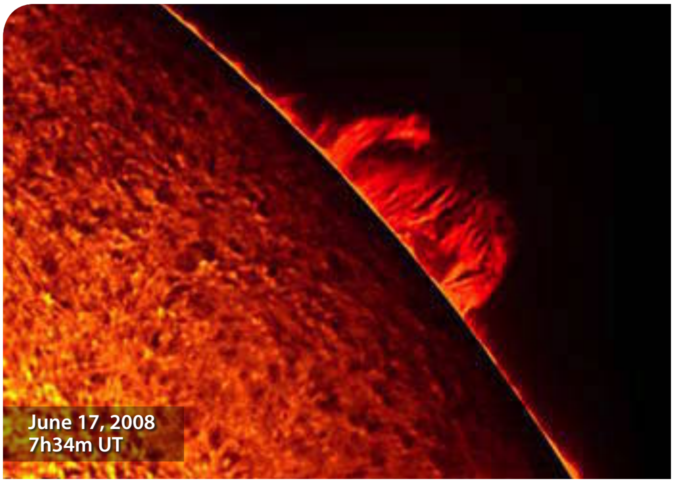
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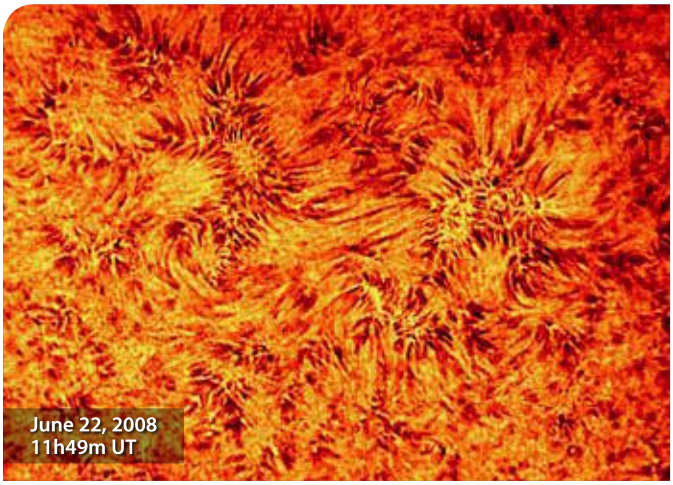
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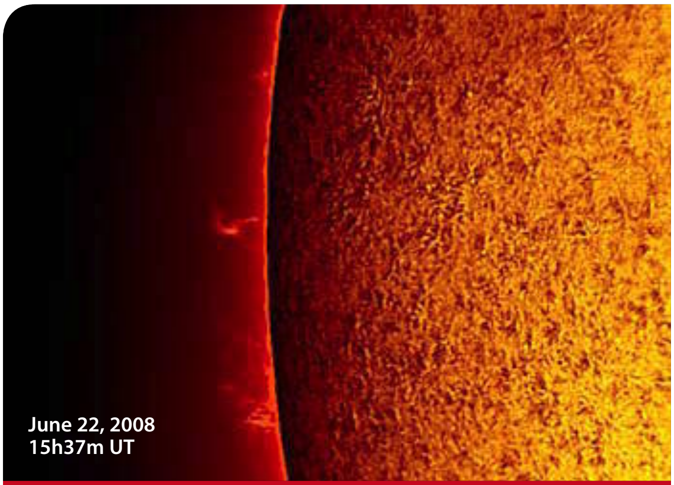
June 22, 2008
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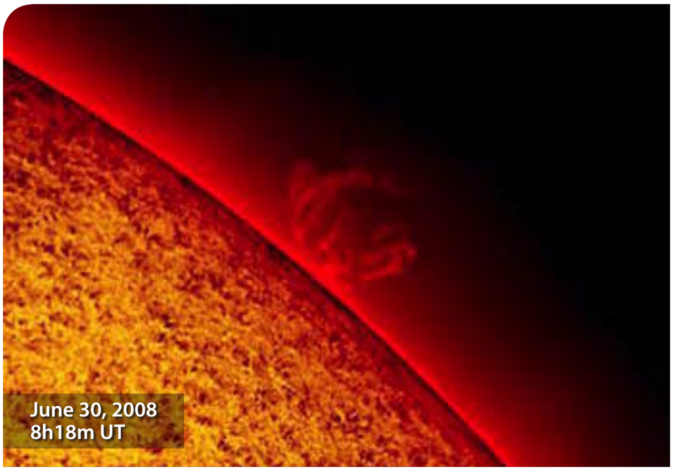
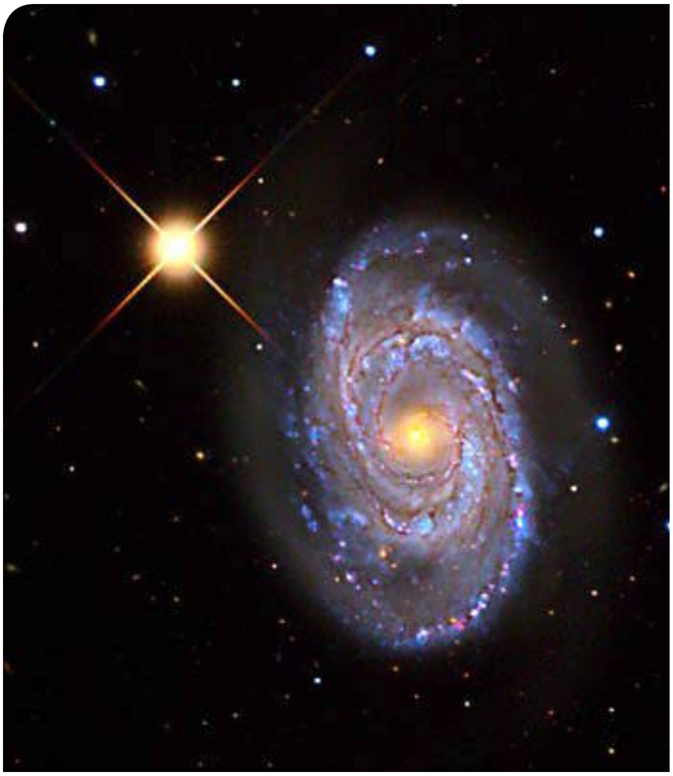

June 30, 2008
8h18m UT

Filtered sunlight (6-inch Vixen refractor and a 3.2-inch TMB 80mm refractor at f/24, f/30, or f/45, DayStar ATM 0.6-angstrom Hydrogen-alpha filter, Lumenera LU075 video camera. 0.016-second exposures for prominences and 0.0045-second exposures for surface detail) • **David Tyler, Flackwell Heath, England**

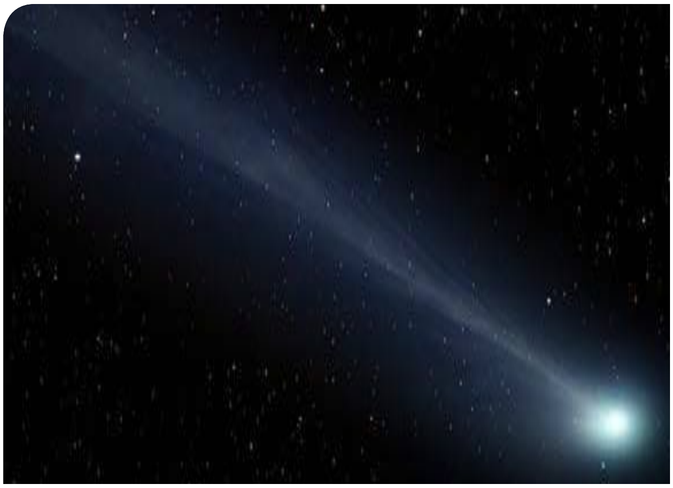
The Sun in H-alpha light

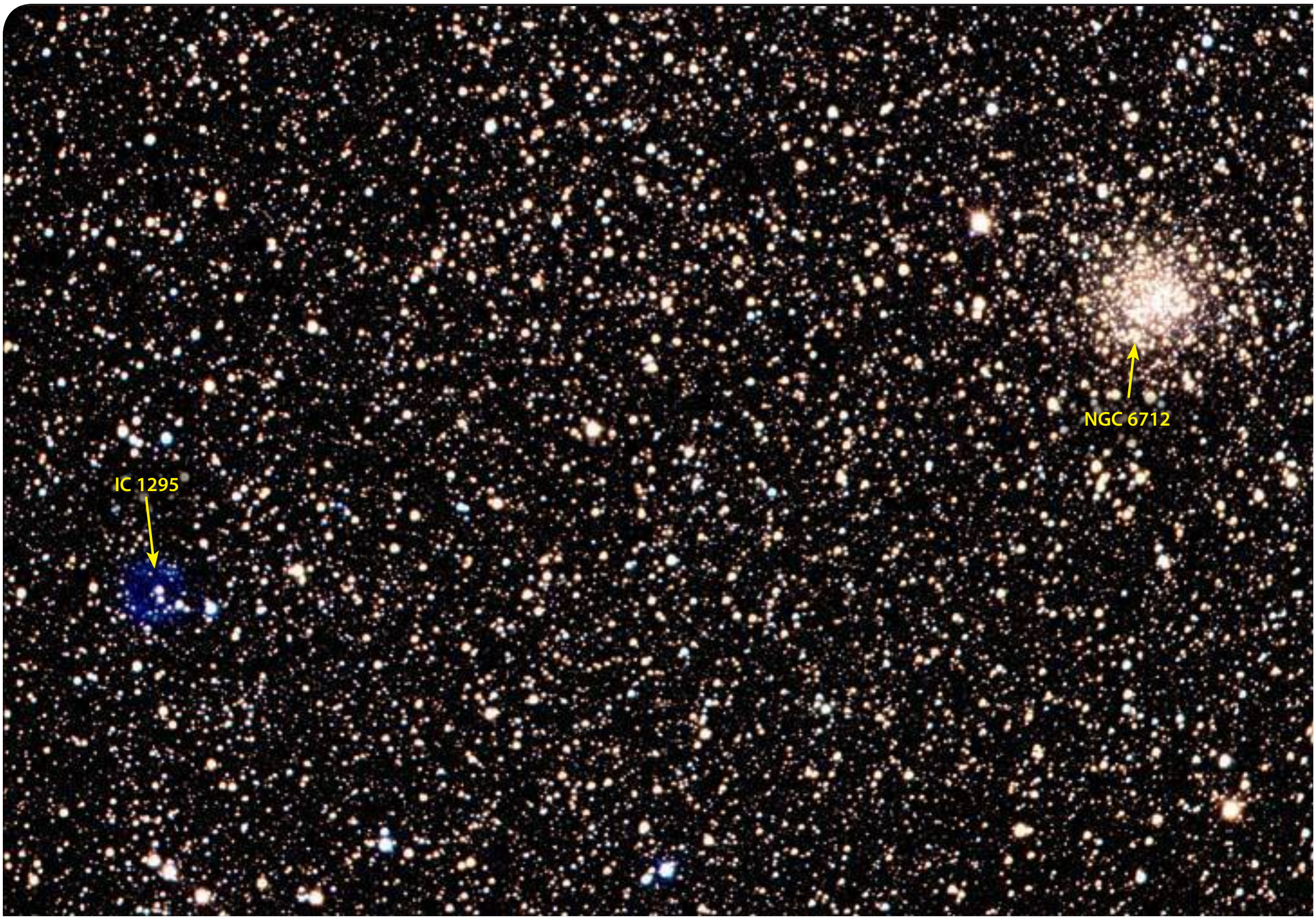
During the past decade, amateur astronomers have purchased Hydrogen-alpha (Hα) telescopes in record numbers. One reason is that manufacturers developed inexpensive Hα scopes. Also, many observers discovered they've been missing half of their potential observing time. Some wanted to try their hands at imaging, so why not start with the sky's brightest object? Whatever the reason, Hα observing is here to stay. And imager David Tyler is just one of many who are chronicling the Sun's ever-changing face.



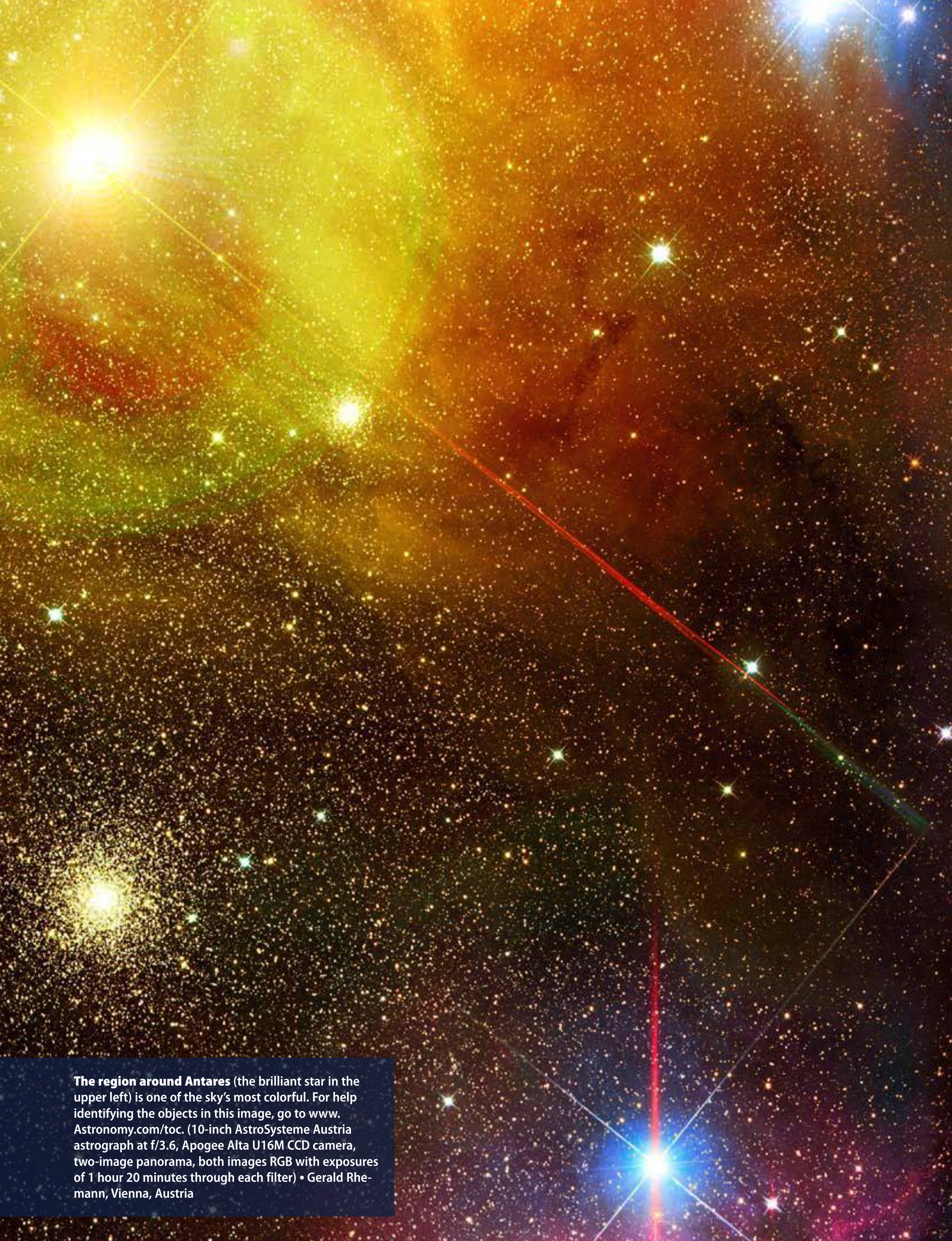
< Spiral galaxy NGC 5371 in Canes Venatici is a magnitude 11 face-on spiral. It measures 4.4' by 3.5'. (24-inch RC Optical Systems Ritchey-Chrétien telescope, SBIG STL-11000 CCD camera, LRGB image with exposures of 120, 30, 20, and 30 minutes, respectively) Adam Block, Mount Lemmon SkyCenter, University of Arizona

V Comet C/2006 M4 (SWAN) first appeared in images June 20, 2006. Later, it became brighter than magnitude 5. (6.4-inch Astro-Physics 160EDF refractor at f/5.7, SBIG STL-11000M CCD camera, LRGB image with exposures of 15, 9, 9, and 9 minutes, respectively, taken September 28, 2006, at 8:03 P.M. MDT) • Ray Gralak, San Jose, California





Globular cluster NGC 6712 and faint planetary nebula IC 1295 reside in the small constellation Scutum the Shield. The cornflower-blue planetary glows weakly at magnitude 15, while the globular blazes by comparison at magnitude 8.7. (12.5-inch homemade Newtonian reflector at f/5, SBIG ST-10XME CCD camera, LRGB image with exposures of 60, 20, 20, and 20 minutes, respectively) • Chris Schur, Payson, Arizona



The region around Antares (the brilliant star in the upper left) is one of the sky's most colorful. For help identifying the objects in this image, go to www.Astronomy.com/toc. (10-inch AstroSysteme Austria astrograph at f/3.6, Apogee Alta U16M CCD camera, two-image panorama, both images RGB with exposures of 1 hour 20 minutes through each filter) • Gerald Rhemann, Vienna, Austria

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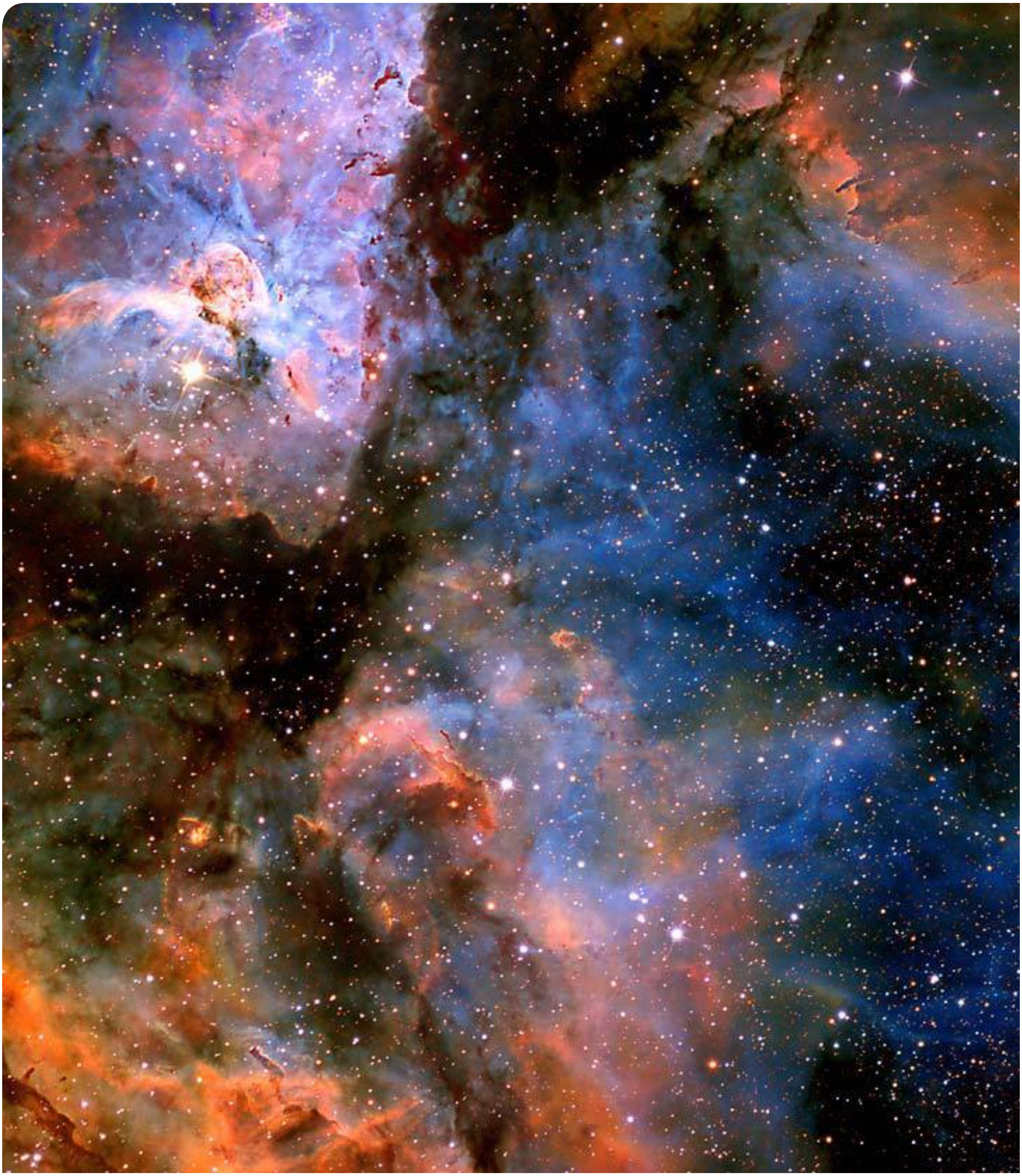

The Eta Carinae Nebula (NGC 3372) lies 7,500 light-years from Earth in the far-southern constellation Carina the Keel. It measures about 1 light-year across and expands at 1.5 million mph (2.4 million km/h). About 150 years ago, the star Eta Carinae underwent a giant outburst. At that time, it became the second-brightest star in the sky. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope, Apogee Alta U16M CCD camera, RGB/SII/Hα/OIII image, with exposures of 8, 8, 8, 90, 80, and 80 minutes, respectively) **• Don Goldman, Orangevale, California**

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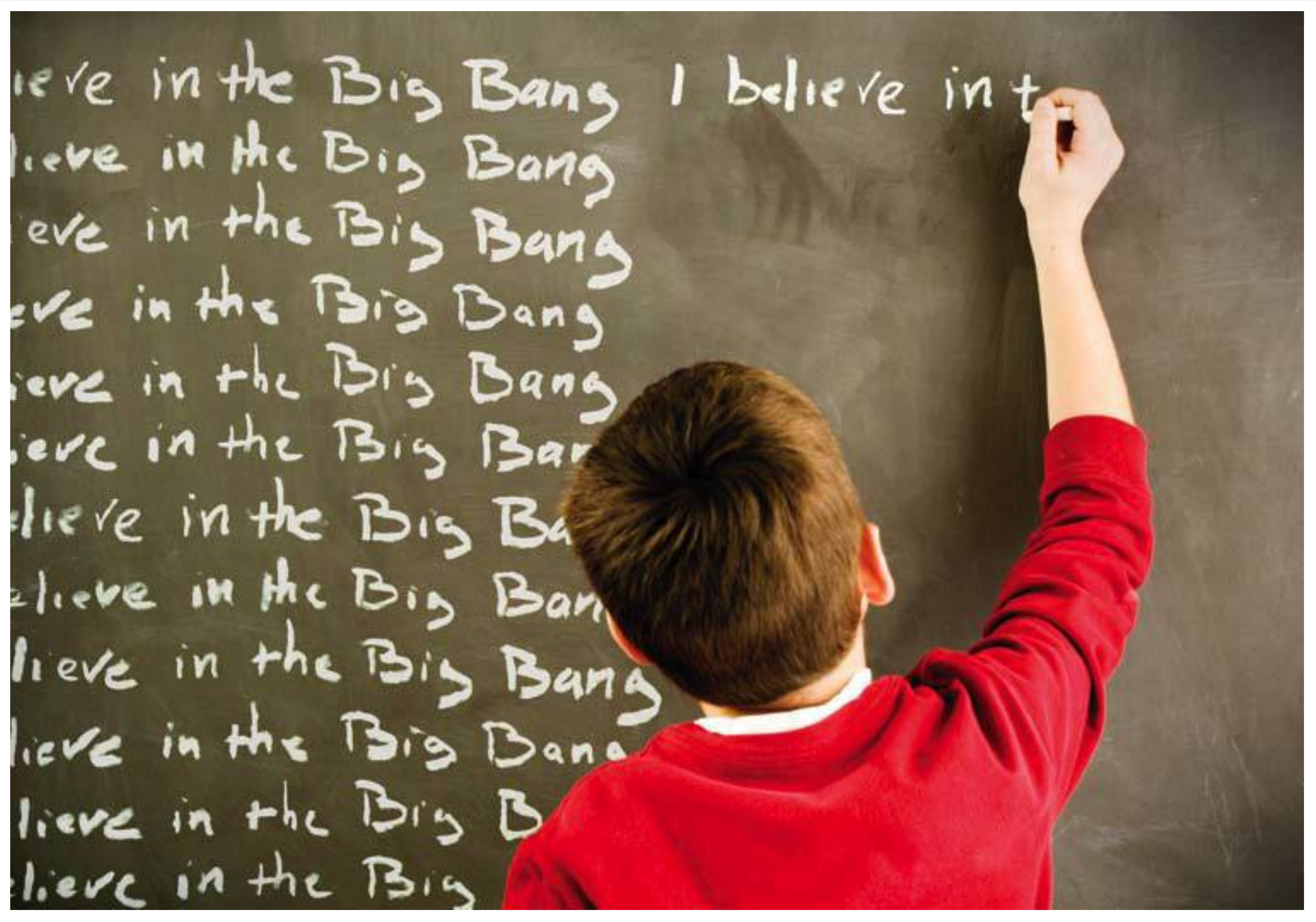
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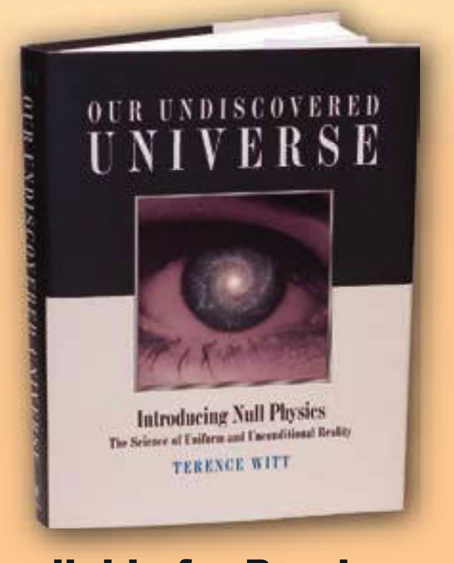
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Astronomy magazine

Sky Guide 2009

By Martin Ratcliffe
and Richard Talcott

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The Sun's corona is on view for more than 5 minutes in parts of China during the July 22 total solar eclipse. Leslie Marczi

Martin Ratcliffe *provides professional planetarium development for Sky-Skan Inc.* **Richard Talcott** *is a senior editor of* Astronomy *magazine.*

A supplement to *Astronomy* magazine

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2008
Dec

S	M	T	W	T	F	S
	1	2	3	4	◐	6
7	8	9	10	11	●	13
14	15	16	17	18	◑	20
21	22	23	24	25	26	○
28	29	30	31			

1	The Moon passes 1.3° south of Jupiter, 10 A.M. EST	👁 👓
	The Moon passes 0.8° north of Venus, 11 A.M. EST	👁 👓 🔭
4	Asteroid Pallas is at opposition, noon EST	👓 🔭
5	Mars is in conjunction with the Sun, 5 P.M. EST	
13	Geminid meteor shower peaks	👁
18	The Moon passes 6° south of Saturn, 10 P.M. EST	👁 👓
21	Solstice (northern winter/southern summer begins), 7 A.M. EST	👁
22	Pluto is in conjunction with the Sun, 4 A.M. EST	
25	The Moon passes 0.09° north of Antares, 2 A.M. EST	👁 👓 🔭
26	Venus passes 1.5° south of Neptune, 9 P.M. EST	👓
28	The Moon passes 0.7° north of Mercury, 11 P.M. EST	👁 👓 🔭
29	The Moon passes 0.6° south of Jupiter, 4 A.M. EST	👁 👓 🔭
31	Mercury passes 1.3° south of Jupiter, 1 A.M. EST	👁 👓
	The Moon passes 3° north of Venus, 4 P.M. EST	👁 👓

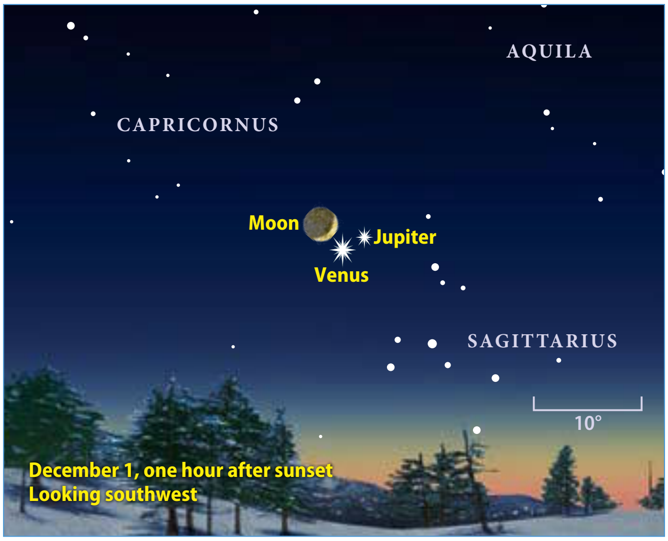
👁 Events that can be viewed with **the naked eye**

👓 Events that can be viewed with **binoculars**

🔭 Events that can be viewed with a **telescope**

The Moon meets a planet pair

A crescent Moon joins Venus (the brighter of the two starlike objects to the upper left) and Jupiter before dawn in February 2008. Tunç Tezel



The evening sky hosts a grand conjunction December 1, when a waxing crescent Moon joins Venus and Jupiter. *Astronomy*: Roen Kelly

A crescent Moon joins the two brightest planets in an evening union in early December. Dazzling Venus, shining at magnitude –4.2, shares the stage with Jupiter, noticeably fainter at magnitude –2.0. On December 1, the two lie 2° apart, or 4 Moon-widths. A waxing crescent Moon stands 3° east of the stunning pair.

When viewed through a telescope, Venus' disk appears 17" across and 69 percent illuminated. Compare its phase with the Moon, which appears 15 percent lit.

Jupiter, being an outer planet, always displays a fully illuminated disk. With an equatorial diameter of 34", it doubles Venus' apparent size. As you look at the two planets, consider that Venus lies 93 million miles from Earth December 1, while Jupiter lies nearly 6 times farther away. Jupiter appears so much bigger than Venus because it's 12 times larger.

The two planets lie a fraction of a degree closer to each other November 30. The scene won't be quite as breathtaking then because the younger Moon lies 8° to Venus' lower right.

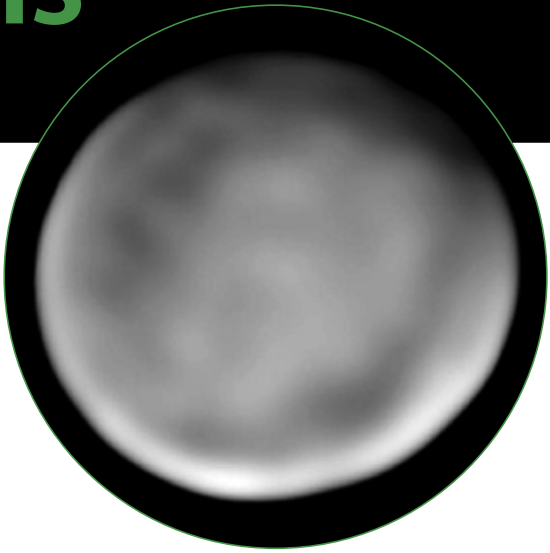
During December, Venus moves eastward and climbs higher as it heads toward its January 2009 greatest elongation. Meanwhile, Jupiter's angular distance from the Sun declines as it moves toward solar conjunction. On the 5th, the two lie 5° apart, and nearly 10° separate them December 10.

Conjunctions between Venus and Jupiter happen fairly often, although they frequently occur close enough to the Sun that the planets don't appear in a dark sky. The two were close to each other in the morning sky in February 2008. The last nice evening conjunction occurred in September 2005, and the next won't come until March 13, 2012, when the planets will lie 3° apart.

A dwarf planet beckons

2009
Jan

S	M	T	W	T	F	S
				1	2	3
◑	5	6	7	8	9	●
11	12	13	14	15	16	◐
18	19	20	21	22	23	24
25	○	27	28	29	30	31



Asteroid 1 Ceres comes closer to Earth during this apparition than at any time in the past 150 years. Keck Observatory/C. Dumas (NASA/JPL)

Asteroid 1 Ceres starts the year as a nice binocular target. It appears even brighter by the time it reaches opposition (when it lies opposite the Sun in our sky) February 25. It then glows at magnitude 6.9 and shows up easily through binoculars.

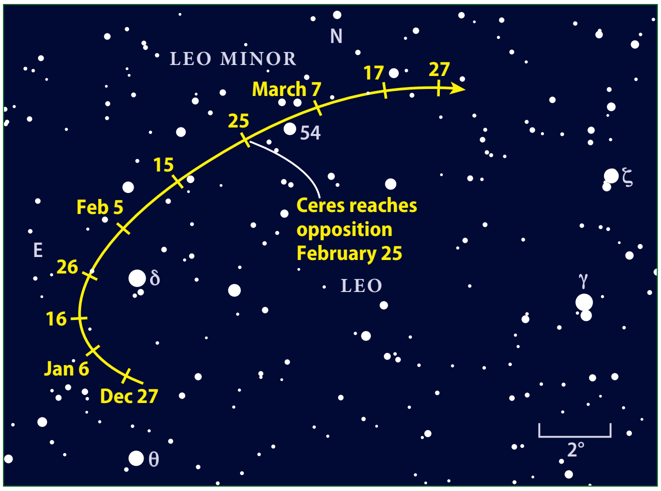
Ceres wanders through northern Leo during January and February, then crosses into Leo Minor in early March. Use the chart below to home in on Ceres. The easiest time to locate Ceres is when it passes near a bright star. The asteroid cooperates nicely this year.

From late December 2008 into early February, Ceres loops around 3rd-magnitude Delta (δ) Leonis. On December 25, you'll find the 8th-magnitude asteroid 2.8° due south of the star. That's about half the field of view of 7x50 binoculars. Center the star in your binoculars, and Ceres will lie near the field's bottom. Don't confuse Ceres with two stars of similar magnitude also south of Delta Leonis. The stars lie just 0.5° from Delta.

One month later, on January 26, Ceres stands 1.5° east of Delta. The asteroid then passes 1.8° north of the star February 8. By opposition, Ceres lies near Leo's border with Leo Minor.

On February 28, Ceres lies 0.6° east of 4th-magnitude 54 Leonis, and it's half that distance north of this star March 5. The asteroid crosses back into Leo at the end of March, by which time it has faded to magnitude 7.4. On May 1, the 8th-magnitude object lies 4° east of Zeta (ζ) Leonis, a 3rd-magnitude star in Leo's Sickle asterism.

Ceres measures 590 miles across, too small for any backyard telescope to reveal its disk. However, it is big enough that gravity has pulled it into a spherical shape. It's the only one of the hundreds of thousands of asteroids that can make this claim. In 2006, the International Astronomical Union designated Ceres as one of the first three dwarf planets, along with Pluto and Eris.



The closest dwarf planet to Earth, Ceres becomes an easy binocular object in northern Leo during January and February. *Astronomy*: Roen Kelly

2 The Moon passes 5° north of Uranus, noon EST

3 Quadrantid meteor shower peaks

4 Mercury is at greatest eastern elongation (19°), 9 A.M. EST

14 Venus is at greatest eastern elongation (47°), 4 P.M. EST

15 The Moon passes 6° south of Saturn, 7 A.M. EST

18 Asteroid Juno is in conjunction with the Sun, 5 P.M. EST

20 Mercury is in inferior conjunction, 11 A.M. EST

21 The Moon passes 0.02° north of Antares, 8 A.M. EST

23 Venus passes 1.4° north of Uranus, 11 A.M. EST

24 Jupiter is in conjunction with the Sun, 1 A.M. EST

26 Annular solar eclipse, 3 A.M. EST

27 The Moon passes 1.8° north of Neptune, 1 P.M. EST

29 The Moon passes 5° north of Uranus, 8 P.M. EST

30 The Moon passes 3° north of Venus, 7 A.M. EST

Spy winter's bright comet

Feb 2009

S	M	T	W	T	F	S
1	◐	3	4	5	6	7
8	○	10	11	12	13	14
15	◑	17	18	19	20	21
22	23	●	25	26	27	28

9	Penumbral lunar eclipse, 10 A.M. EST	👁 🔍 🔭
11	The Moon passes 6° south of Saturn, 3 P.M. EST	👁 🔍
12	Neptune is in conjunction with the Sun, 8 A.M. EST	
13	Mercury is at greatest western elongation (26°), 4 P.M. EST	👁 🔍 🔭
17	Mars passes 0.6° south of Jupiter, 5 A.M. EST	👁 🔍 🔭
	The Moon passes 0.04° north of Antares, 4 P.M. EST	👁 🔍 🔭
19	Venus reaches greatest brilliancy, 10 A.M. EST	👁 🔍 🔭
22	The Moon passes 1.1° north of Mercury, 5 P.M. EST	👁 🔍 🔭
	The Moon passes 0.7° north of Jupiter, 8 P.M. EST	👁 🔍 🔭
23	The Moon passes 1.7° north of Mars, 3 A.M. EST	👁 🔍
	Mercury passes 0.6° south of Jupiter, 10 P.M. EST	👁 🔍 🔭
25	Asteroid Ceres is at opposition, 9 A.M. EST	🔍 🔭
27	The Moon passes 1.3° south of Venus, 6 P.M. EST	👁 🔍 🔭

Comet C/2007 N3 (Lulin) appeared as a faint fuzzball last July, when it still was far from the Sun and Earth. Michael Jäger

February's night sky welcomes an unexpected visitor: Comet C/2007 N3 (Lulin). This cosmic guest comes closest to Earth this month and should glow around 6th magnitude — bright enough to see easily through binoculars. Chinese astronomers Quanzhi Ye and Chi Sheng Lin (members of the Lulin Sky Survey) discovered the comet in July 2007.

Comet Lulin reaches perihelion, the point in its orbit closest to the Sun, January 10. The comet lies in the morning sky then, 3° west of Beta (β) Scorpii. At 8th magnitude, it will be a tricky binocular object. (Treat these magnitude estimates with a grain of salt — new comets are unpredictable, and Lulin could be noticeably fainter or brighter.)

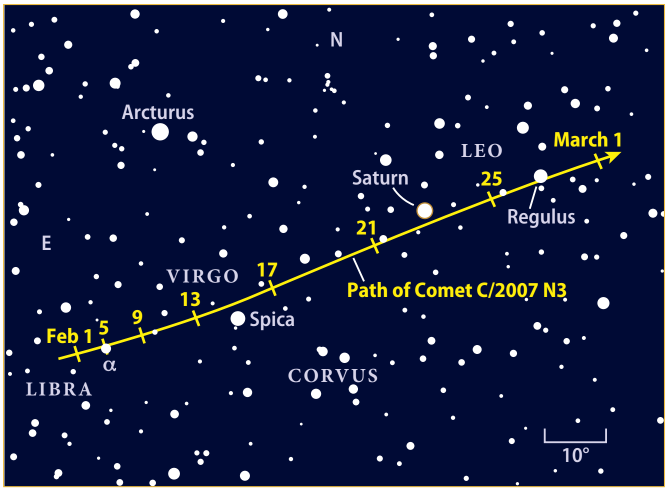
During the next 6 weeks, Comet Lulin brightens significantly and remains visible longer each night. On February 6, it lies near Alpha (α) Librae and should shine at 7th magnitude. Its distance from Earth shrinks from 150 million miles in early January to 75 million miles by February's first week. In just the next 2 weeks, Lulin cuts this distance in half again.

As it approaches Earth, Comet Lulin brightens and swings westward. In mid-February, you can find it crossing Virgo, although a bright Moon interferes. On the 16th, Lulin passes 3° north of Spica while the Last Quarter Moon shines to the east in Libra. The Moon soon leaves the scene, and the 6th-magnitude comet will be on display longer each night.

Lulin moves westward rapidly, and the comet rises 20 minutes earlier each night. On February 19/20, it rises shortly before 9 P.M. local time. Five days later, at its closest point to Earth (38 million miles), it rises around 6:30 P.M. It then lies just 2° southwest of Saturn, making it a cinch to find.

As February comes to an end, the comet passes near Leo's brightest star, Regulus. It crosses into Cancer in early March, having faded to 7th magnitude. It lies south of the Beehive star cluster (M44) March 5, but a waxing gibbous Moon will make comet viewing difficult.

Once the Moon leaves the area, Comet Lulin fades to 8th magnitude and crosses into Gemini. It remains among the Twin's stars as it recedes into the solar system's depths.



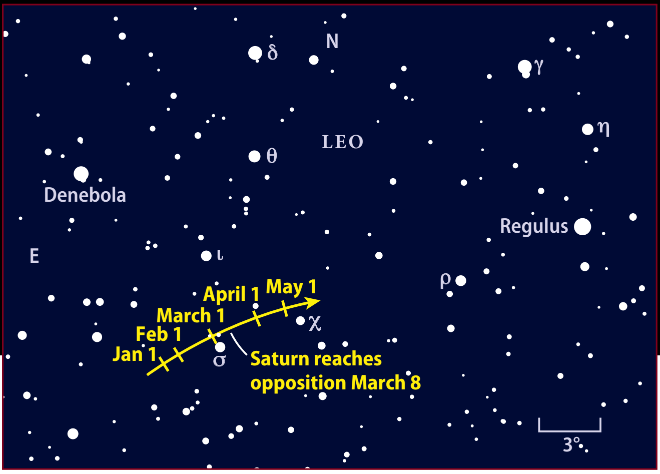
When Comet Lulin makes its closest approach to Earth in late February, it should glow around 6th magnitude. *Astronomy*: Roen Kelly

Saturn loses its rings

2009

March

S	M	T	W	T	F	S
1	2	3	◑	5	6	7
8	9	●	11	12	13	14
15	16	17	◐	19	20	21
22	23	24	25	○	27	28
29	30	31				



Saturn shines brightly this winter and spring, when it appears as the brightest starlike object in the constellation Leo. *Astronomy*: Roen Kelly

Glorious Saturn reaches opposition and peak visibility March 8. It then shines brighter (at magnitude 0.5) than at any other time this year. Saturn appears among the background stars of southern Leo, beneath the celestial Lion's hindquarters.

Saturn ranks near the top of almost every observer's list of favorite targets. The reason: the planet's bright rings. Although all four of the solar system's giant planets have ring systems, only Saturn's icy rings reflect enough light to appear prominent from Earth.

Yet first-time viewers this year might wonder what the hoopla's all about. For most of 2009, the rings will be hard to see — if they're visible at all.

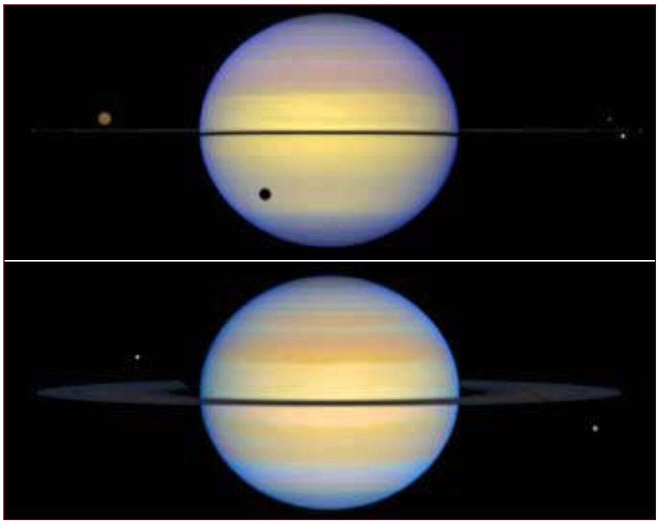
Twice each saturnian year, which lasts 29.5 Earth years, Saturn's equatorial plane coincides with its orbital plane. (Earth experiences a similar alignment with the Sun at the vernal and autumnal equinoxes.) Because Saturn's rings lie in the same plane as its equator, the rings then tilt edge-on to the Sun. And those of us on Earth get much the same view of a Saturn without rings.

At the March 8 opposition, the rings tilt 3° to our line of sight. Backyard observers with clear skies and good seeing conditions may catch them as a thin streak on both sides of the planet's 20"-diameter disk. The ring tilt increases to 4° in May, then reverses course.

The actual ring-plane crossing occurs when Saturn lies on the opposite side of the Sun from Earth. The rings tilt edge-on to the Sun August 10, and edge-on to Earth September 4. By the time Saturn returns to view in early October's morning sky, the Sun will be illuminating the northern side of the rings for the first time since 1995.

October also brings two nice conjunctions involving Saturn. On the 8th, Mercury lies just 0.3° south of the ringed planet. Five days later, brilliant Venus passes 0.6° south of Saturn. Both conjunctions happen against the background stars of Virgo the Maiden. Binoculars should provide the best views for both events.

The rings' tilt increases throughout the rest of 2009, reaching 5° by year's end, and will continue to grow for several years. They reach a maximum tilt of 32° in 2017. The cycle will then reverse and the rings will narrow until the next ring-plane crossing in 2025.



Saturn's rings will disappear for many backyard observers during much of 2008, as the rings turn edge-on to our line of sight. Erich Karkoschka (LPI)/NASA

1	Mercury passes 0.6° south of Mars, 3 P.M. EST
7	Mars passes 0.8° south of Neptune, 11 P.M. EST
8	Saturn is at opposition, 4 P.M. EDT
10	The Moon passes 6° south of Saturn, 11 P.M. EDT
12	Uranus is in conjunction with the Sun, 9 P.M. EDT
17	The Moon passes 0.2° north of Antares, 1 A.M. EDT
20	Equinox (northern spring/southern autumn begins), 8 A.M. EDT
22	The Moon passes 1.5° north of Jupiter, 5 P.M. EDT
23	The Moon passes 2° north of Neptune, 10 A.M. EDT
24	The Moon passes 4° north of Mars, 10 A.M. EDT
27	Venus is in inferior conjunction, 3 P.M. EDT
30	Mercury is in superior conjunction, 11 P.M. EDT

For more on these and other sky events throughout the year, go to Astronomy.com.

2009

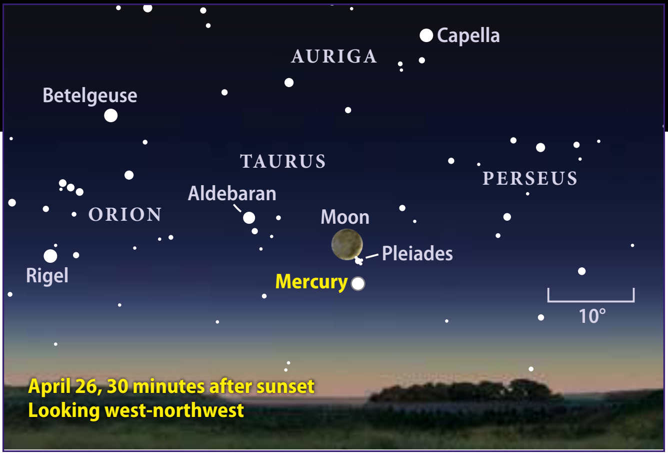
April

S	M	T	W	T	F	S
			1	◑	3	4
5	6	7	8	●	10	11
12	13	14	15	16	◐	18
19	20	21	22	23	○	25
26	27	28	29	30		

7	The Moon passes 6° south of Saturn, 3 A.M. EDT	👁 ∞
13	The Moon passes 0.4° north of Antares, 9 A.M. EDT	👁 ∞ 🔭
14	Mars passes 0.5° south of Uranus, midnight EDT	∞ 🔭
18	Venus passes 6° north of Mars, 1 P.M. EDT	👁 ∞
19	The Moon passes 2° north of Jupiter, noon EDT	👁 ∞
	The Moon passes 2° north of Neptune, 8 P.M. EDT	∞
22	The Moon passes 5° north of Uranus, 4 A.M. EDT	∞
	Lyrid meteor shower peaks	👁
	The Moon passes 1.1° north of Venus, 10 A.M. EDT	👁 ∞ 🔭
	The Moon passes 6° north of Mars, 3 P.M. EDT	👁 ∞
26	Mercury is at greatest eastern elongation (20°), 4 A.M. EDT	👁 ∞ 🔭
	The Moon passes 1.9° north of Mercury, noon EDT	👁 ∞

Mercury at its evening best

Mercury's best evening appearance of 2009 comes in late April, when it passes near the Pleiades star cluster (M45). *Astronomy:* Roen Kelly



For those of us in the Northern Hemisphere, Mercury remains elusive. The innermost planet rarely appears in a dark sky; instead, it hovers in twilight even at its best. Mercury comes into view clearly only a few times each year, and then for just a couple of weeks. This year, the best time for evening observers to spy Mercury comes in late April and early May.

The planet reaches greatest eastern elongation April 26, when it lies 20° from the Sun. Mercury stands 13° above the west-northwestern horizon 30 minutes after sunset. To make finding Mercury easier, a crescent Moon lies 5° above the planet. Shining at magnitude 0, the planet should pierce through the twilight without difficulty. If you have trouble seeing it with your naked eyes, try binoculars. The optical aid also reveals the Pleiades star cluster (M45) between the Moon and Mercury.

During the next few days, the Moon leaves the scene while Mercury edges closer to the Pleiades. On April 29, the planet lies 1° away.

If you enjoy stargazing before dawn, mark your calendar for October. On the night of October 5/6, Mercury reaches greatest western elongation. It then lies 18° from the Sun and appears 11° high in the east 30 minutes before sunrise. Although the Moon doesn't lie close by, Venus makes an impressive guide. Mercury sits 6° below the brilliant planet. Binoculars will bring fainter Saturn into view as well, some 2° to Mercury's lower left.

April evenings and October mornings may be the best times to find Mercury this year, but they aren't the only ones. The planet also appears on evenings in early January and mid-December, and on mornings in mid-February and mid-June.

Mercury appears different from one greatest elongation to the next because the ecliptic — the apparent path of the Sun and planets across the sky — changes orientation to the horizon. If the ecliptic makes a steep angle to the horizon, most of the planet's elongation from the Sun translates into altitude. Conversely, if the ecliptic makes a shallow angle to the horizon, Mercury remains buried in twilight.

Heavily cratered Mercury appears too small and lies too near the Sun to show any detail through a backyard telescope. NASA/JHUAPL/CIW

Planets flourish on spring mornings

Five bright planets line up in the May 2002 evening sky. A crescent Moon and a saguaro cactus complete the scene. Joe Orman

Six planets gather in this spring's morning sky. Five of them come into view around mid-April, but they gain significant altitude during May. These five — Venus, Mars, Jupiter, Uranus, and Neptune — span 40° in early May. Mercury joins the group in June.

The lineup of planets starts in Capricornus, where we find Jupiter and Neptune. It then extends eastward to Pisces, where Uranus lingers. In April and May, the string's eastern end lies in Pisces, where Venus and Mars reside. Both move into Aries in early June, but by then Mercury holds the easternmost position in Taurus.

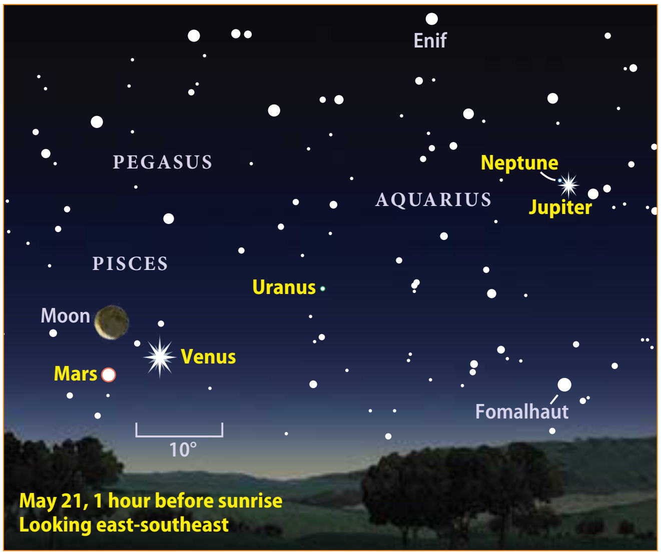
April 19 is a good morning to start watching. Half an hour before sunrise, Venus and Mars stand 5° apart low in the east. Nearly 40° to their upper right, you'll find Jupiter paired with a crescent Moon. Uranus and Neptune lie between these two pairs.

In early May, Jupiter rises 3 hours before the Sun and Neptune lies 2° to Jupiter's left. Jupiter passes 0.4° south of Neptune May 25.

Uranus begins May near the Venus-Mars pair. By month's end, it has moved halfway toward the Jupiter-Neptune pair.

Mars and Venus are the most exciting pair. On May 21, a crescent Moon forms a pretty triangle with the planets. And on June 19, Venus and Mars stand just 2° apart.

The five planets continue their dance into June, but with the addition of Mercury. The inner planet should be easy to pick out of the twilight in mid-June.



Another planetary alignment greets viewers this spring, although prime viewing will come before dawn. *Astronomy*: Roen Kelly

2009 May

S	M	T	W	T	F	S
					◐	2
3	4	5	6	7	8	○
10	11	12	13	14	15	16
◑	18	19	20	21	22	23
●	25	26	27	28	29	◐
31						

2 Venus is at greatest brilliancy, 11 A.M. EDT

4 The Moon passes 6° south of Saturn, 7 A.M. EDT

5 Eta Aquarid meteor shower peaks

10 The Moon passes 0.6° north of Antares, 5 P.M. EDT

17 The Moon passes 3° north of Jupiter, 4 A.M. EDT

The Moon passes 3° north of Neptune, 5 A.M. EDT

18 Mercury is in inferior conjunction, 6 A.M. EDT

19 The Moon passes 5° north of Uranus, 4 P.M. EDT

21 The Moon passes 7° north of Venus, 4 A.M. EDT

The Moon passes 7° north of Mars, 4 P.M. EDT

25 Jupiter passes 0.4° south of Neptune, 9 A.M. EDT

31 The Moon passes 6° south of Saturn, 1 P.M. EDT

2009
June

S	M	T	W	T	F	S
	1	2	3	4	5	6
●	8	9	10	11	12	13
14	◐	16	17	18	19	20
21	○	23	24	25	26	27
28	◑	30				

5 Venus is at greatest western elongation (46°), 5 P.M. EDT

6 The Moon passes 0.6° north of Antares, midnight EDT

13 Mercury is at greatest western elongation (23°), 8 A.M. EDT

The Moon passes 3° north of Neptune, noon EDT

The Moon passes 3° north of Jupiter, 2 P.M. EDT

16 The Moon passes 6° north of Uranus, 2 A.M. EDT

19 Venus passes 2° south of Mars, 10 A.M. EDT

The Moon passes 6° north of Mars, 1 P.M. EDT

The Moon passes 8° north of Venus, 1 P.M. EDT

21 Solstice (northern summer/southern winter begins), 2 A.M. EDT

The Moon passes 7° north of Mercury, 5 A.M. EDT

22 Asteroid Vesta is in conjunction with the Sun, 8 A.M. EDT

Mercury passes 3° north of Aldebaran, 10 A.M. EDT

23 Pluto is at opposition, 4 A.M. EDT

27 The Moon passes 7° south of Saturn, 10 P.M. EDT

Summer's deep-sky splendors

The Lagoon Nebula (M8) appears as a fuzzy blob to the naked eye, but it explodes with detail through a telescope. Gerald Rhemann

There's no time like summer to explore the Milky Way's store of deep-sky objects. Even 7x50 binoculars reveal many star clusters and gaseous nebulae under a reasonably dark sky.

Open and globular star clusters stand up to various sky conditions. You can get nice views of these objects even with interfering streetlights. To get the most out of your observing, however, travel outside of town. On a clear night, your binoculars will reveal spectacles most people simply miss.

Head outside around 11 P.M. local daylight time during the second half of June, once the waxing Moon has set. From a dark site, the first major feature you'll notice is the Milky Way climbing in the east. Scan your binoculars along this broad band to see some spectacular star clusters. Also note the dark rifts that bisect the Milky Way in Cygnus.

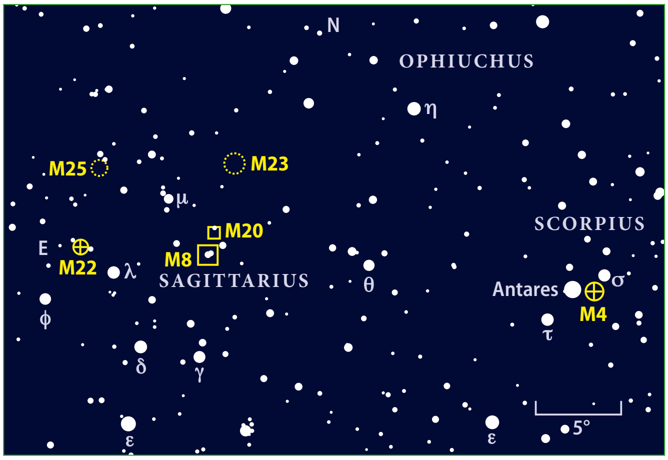
Let's start with an easy globular cluster. First find Antares — Scorpius' brightest star — which shines with a ruddy glow low in the south. Focus your binoculars on Antares, and you'll see two fainter stars, one on either side of Antares. Look midway between and slightly below a line joining Antares and the higher of these fainter stars, and you'll see a small, circular patch of fuzzy light. This is M4, one of the finest of the dozen bright globulars visible in the summer sky.

Now swing back to the southeast, where you'll find Sagittarius' Teapot asterism. Focus on the top star of the teapot's lid, 3rd-magnitude Lambda (λ) Sagittarii. Scan 2° to the upper left and you'll land on an equally impressive globular, M22.

Summer's finest emission nebula lies nearby. Scan 5° to Lambda Sagittarii's upper right and you'll spot a faint patch of light with a distinct shape. This is the Lagoon Nebula (M8) — a cloud of glowing hydrogen gas with an embedded star cluster. Unlike the ancient globular clusters, M8's stars formed within the past few million years.

Head 1.5° above M8 to find the Trifid Nebula (M20). Look for a tiny concentration of light in your binoculars.

Scan 4° farther north and you'll land on the open cluster M23. This cluster formed in a cloud similar to the Lagoon Nebula, but the gas has dissipated. A similar cluster, M25, lies 8° northeast of the Trifid.



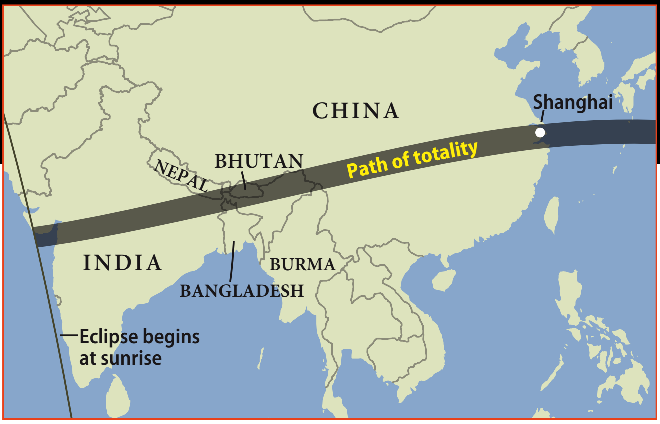
Glorious deep-sky objects proliferate throughout Sagittarius and Scorpius — the direction to our galaxy's central hub. *Astronomy*: Roen Kelly

Totality's long embrace

July 2009

S	M	T	W	T	F	S
			1	2	3	4
5	6	●	8	9	10	11
12	13	14	◐	16	17	18
19	20	○	22	23	24	25
26	27	◑	29	30	31	

The path of totality July 22 starts in India and then heads east, cutting through Nepal, Bangladesh, Bhutan, Burma, and China. *Astronomy*: Roen Kelly



The longest total eclipse of the Sun in nearly 2 decades occurs July 22. At the point of maximum eclipse in the Pacific Ocean, totality lasts 6 minutes and 39 seconds. The path of totality crosses the Chinese coastal city of Shanghai, with a population near 20 million. More people may see this phenomenon than any before.

To find a longer eclipse, you have to go back to July 11, 1991. Totality then lasted 6 minutes and 53 seconds. That shadow crossed the Big Island of Hawaii, Baja California, and mainland Mexico. Both eclipses belong to the same family of eclipses, or Saros, a period of approximately 6,585.3 days.

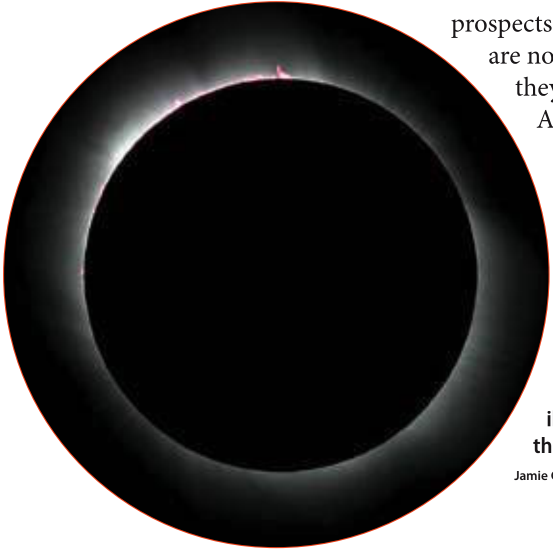
During this month's eclipse, the Moon's shadow first touches land in western India. The path of totality then crosses parts of Nepal, Bangladesh, Bhutan, and then the northern tip of Burma. Within 20 minutes of the shadow reaching Earth, it crosses into China's Sichuan province and the city of Chengdu.

Twenty-five minutes later, the path of totality reaches China's coast. The center line passes just south of Shanghai. This marks the spot with the longest duration on the mainland: 5 minutes and 56 seconds. After the shadow passes over some small Japanese islands, the eclipse reaches its maximum duration beyond Iwo Jima. This island lies within the path of totality but south of the center line.

Unfortunately, weather prospects for this event are not as favorable as they were for the August 1, 2008, eclipse in Russia and China. Weather statistics indicate that much of China experiences 50 to 60 percent cloud cover during July, significantly less than the 70 to 80 percent farther west in India. This year's occurrence lasts more than twice as long as last year's, however, so few eclipse chasers will be dissuaded.

Smog levels run high in many large Chinese cities. If you choose to stay on the mainland, you may have a better chance of seeing totality from sites away from Shanghai, in the higher elevations outside the city.

By July, the newest solar activity cycle should make its presence felt. Observers will be keen to see what the Sun's corona looks like, and whether the long streamers seen during the 2008 eclipse reappear. The corona's delicate appearance, visible from Earth only during a total solar eclipse, ranks among nature's most spectacular sights. Viewers also will target any prominences — vivid pink tongues of hydrogen gas that arc tens of thousands of miles above the Sun's surface.



Ruddy prominences arc above the Sun's surface during totality in March 2006. Expect similar fireworks at this month's eclipse. Jamie Cooper

Date	Event
4	The Moon passes 0.5° north of Antares, 6 A.M. EDT
7	Penumbral lunar eclipse, 5 A.M. EDT
10	The Moon passes 4° north of Jupiter, 6 P.M. EDT
	The Moon passes 3° north of Neptune, 6 P.M. EDT
13	The Moon passes 6° north of Uranus, 8 A.M. EDT
	Jupiter passes 0.6° south of Neptune, 3 P.M. EDT
	Mercury is in superior conjunction, 10 P.M. EDT
14	Venus passes 3° north of Aldebaran, 2 P.M. EDT
18	The Moon passes 5° north of Mars, 8 A.M. EDT
19	The Moon passes 6° north of Venus, 1 A.M. EDT
21	Total solar eclipse, 11 P.M. EDT
25	The Moon passes 7° south of Saturn, 11 A.M. EDT
27	Mars passes 5° north of Aldebaran, 7 A.M. EDT
31	The Moon passes 0.5° north of Antares, noon EDT

2009
Aug

S	M	T	W	T	F	S
						1
2	3	4	●	6	7	8
9	10	11	12	◐	14	15
16	17	18	19	○	21	22
23	24	25	26	◑	28	29
30	31					

2	Mercury passes 0.6° north of Regulus, 3 P.M. EDT
5	Penumbral lunar eclipse, 9 P.M. EDT
6	The Moon passes 3° north of Jupiter, 6 P.M. EDT
	The Moon passes 3° north of Neptune, 10 P.M. EDT
9	The Moon passes 6° north of Uranus, 1 P.M. EDT
12	Perseid meteor shower peaks
14	Jupiter is at opposition, 2 P.M. EDT
15	The Moon passes 3° north of Mars, 11 P.M. EDT
17	Neptune is at opposition, 5 P.M. EDT
	The Moon passes 1.7° north of Venus, 5 P.M. EDT
18	Mercury passes 3° south of Saturn, 5 P.M. EDT
21	Venus passes 7° south of Pollux, midnight EDT
22	The Moon passes 7° south of Saturn, 2 A.M. EDT
	The Moon passes 3° south of Mercury, 8 A.M. EDT
24	Mercury is at greatest eastern elongation (27°), noon EDT
27	The Moon passes 0.6° north of Antares, 6 P.M. EDT

Jupiter shines big and bright

Jupiter's turbulent clouds always put on a colorful and dynamic show for observers with small telescopes. Mike Salway

The long, hot days of summer give way to warm and often pleasant nights — the perfect time to explore the heavens. This year, late summer provides the best views of three giant planets: Jupiter, Uranus, and Neptune. Jupiter reaches opposition and peak visibility first, on August 14.

At opposition, Jupiter shines brilliantly at magnitude –2.9. That makes it the brightest point of light in the sky until Venus rises in the wee hours. And because it lies among the faint background stars of Capricornus, Jupiter dazzles even more. Although the planet appears best at opposition and stays visible all night, it remains well worth viewing for several months.

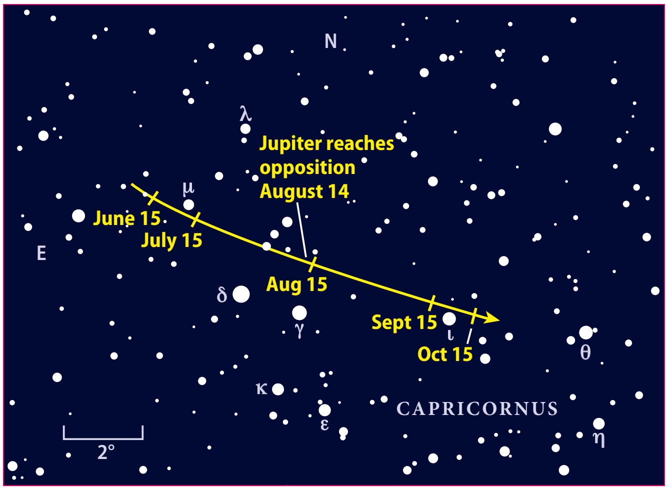
The giant planet's location provides an added incentive for observers with small telescopes. During the previous 2 years, Jupiter wandered the southern constellations of Scorpius, Ophiuchus, and Sagittarius — as far south as it can get. For northern observers, this meant the planet never climbed high in the sky. Looking through additional layers of Earth's atmosphere made Jupiter's features appear blurry more often than not.

But with Capricornus as a backdrop, Jupiter rides higher in the sky and will yield sharper views. And it offers plenty to see. At opposition, the giant planet spans 49". Even a small telescope will show the planet's two dark equatorial belts, one on each side of a brighter equatorial zone. In moments of good seeing, a series of alternating dark belts and lighter zones comes into view. Finer details in Jupiter's dynamic atmosphere tend to gather near the boundaries between belts and zones.

While you're viewing Jupiter, don't miss its four bright moons. Galileo discovered these objects in 1610 — the first proof that Earth was not the center of all motion in the universe. Each night, Io, Europa, Ganymede, and Callisto take up different positions relative to Jupiter.

Three days after Jupiter reaches opposition, Neptune does the same. As you might guess, the coincidence in time translates into a proximity in space. Neptune lies just 3° northeast of Jupiter in mid-August. Glowing at 8th magnitude, Neptune appears as a dot through binoculars. A telescope shows a blue-gray disk 2.4" across.

Uranus reaches opposition 1 month after Neptune, on September 17. Uranus then lies in southern Pisces, about 5° due south of Lambda (λ) Piscium. The planet shines at magnitude 5.7 and can be glimpsed with the naked eye under a dark sky. A telescope reveals its 3.7"-diameter disk, which glows with a blue-green hue.

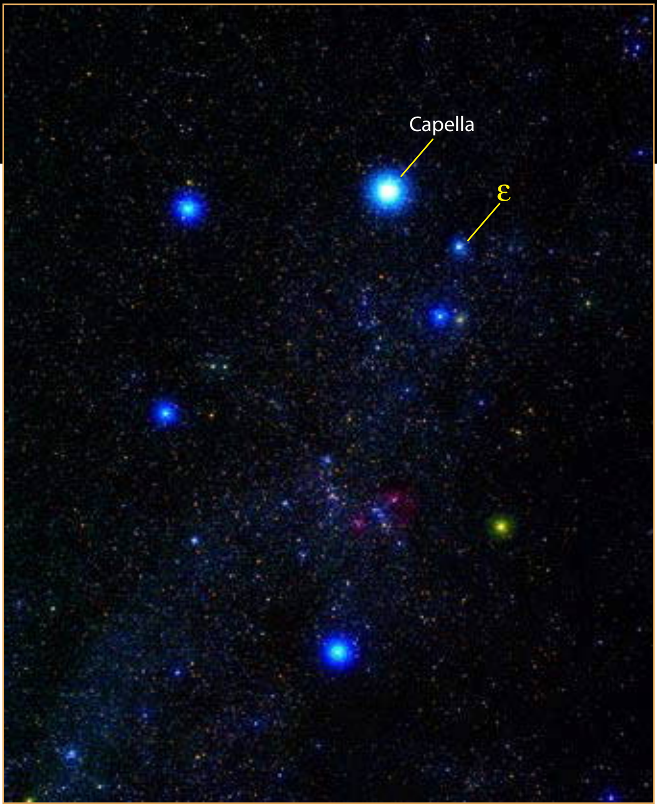


Jupiter wanders the inconspicuous background stars of Capricornus when it shines brightest this summer and fall. *Astronomy*: Roen Kelly

The sky's oddest star

Epsilon (ε) Aurigae — the bright star located just southwest of brilliant Capella — dims this year as it starts a nearly 2-year eclipse.

Bill and Sally Fletcher



Every 27 years, Epsilon (ε) Aurigae dims by a full magnitude during a strange eclipse that still puzzles astronomers. Caused by a mysterious dark object of unknown identity, the eclipse lasts nearly 2 years, the longest duration of any known eclipsing binary. Researchers predict the next eclipse will begin August 6, and this partial phase should become noticeable by September. The eclipse won't end until May 2011.

Third-magnitude Epsilon Aurigae shows up easily to the naked eye even from the suburbs. You can find it just 3° southwest of Capella, Auriga the Charioteer's brightest star. This region lies far enough north that it's visible from mid-northern latitudes most of the year. In September, the constellation rises in the northeast by 9 P.M. local daylight time and lies nearly overhead at dawn.

In eclipsing binaries, the primary star dims when a secondary star passes in front of it. Normally, the eclipse lasts a few hours. Yet the total phase of Epsilon's eclipse extends 446 days (from December 21, 2009, to March 12, 2011, if predictions hold). This means the secondary must be huge.

Curiously, this occulting object remains invisible. Astronomers suspect it's a cold, dark accretion disk seen edge-on. The primary star's spectrum stays in view during totality, however, suggesting the disk must be semi-transparent. And what kind of central object keeps the disk stable? No one knows, although some researchers think two stars may lie at the disk's center.

The best model indicates that a hole in the accretion disk will come into view at mid-eclipse (August 2010), causing the system to brighten slightly. Such a brightening occurred during the two previous eclipses, in 1956 and 1983.

To add to this star's uniqueness, the duration of totality has increased by 25 percent while the partial phases have shrunk. These indicate major changes in the accretion disk's size. If the trends continue, the predicted 64-day closing partial phase may take only 14 days. Perhaps the disk is collapsing onto whatever object or objects lie at its center.

Many telescopes will keep an eye on Epsilon before, during, and after the eclipse. Researchers are organizing an international observing campaign. And they encourage the general public to take part. All you need to do is measure the star's changing brightness, a task made easier by the advent of digital cameras. For details on this system and how you can get involved, visit the web site of the American Association of Variable Star Observers at www.aavso.org/vstar/vsots/eps_aur.shtml.

2009
Sept

S	M	T	W	T	F	S
		1	2	3	○	5
6	7	8	9	10	◑	12
13	14	15	16	17	●	19
20	21	22	23	24	25	◐
27	28	29	30			

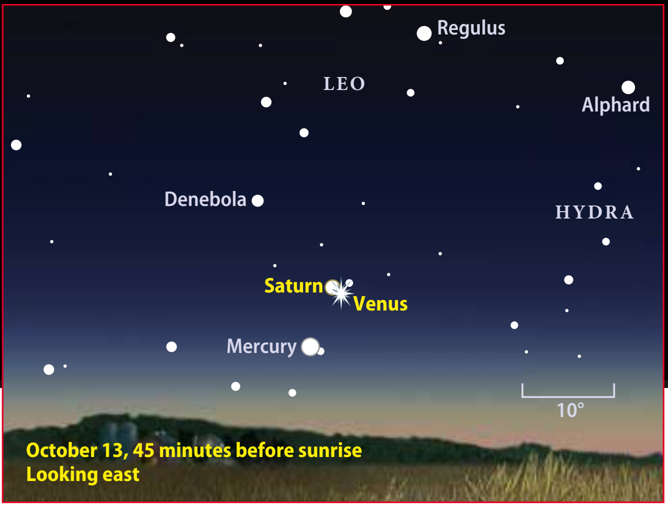
2	The Moon passes 3° north of Jupiter, 5 P.M. EDT
3	The Moon passes 3° north of Neptune, 3 A.M. EDT
5	The Moon passes 6° north of Uranus, 5 P.M. EDT
12	Asteroid Pallas is in conjunction with the Sun, 8 P.M. EDT
13	The Moon passes 1.1° north of Mars, noon EDT
16	The Moon passes 3° south of Venus, 2 P.M. EDT
17	Uranus is at opposition, 6 A.M. EDT
	Saturn is in conjunction with the Sun, 2 P.M. EDT
20	Mercury is in inferior conjunction, 6 A.M. EDT
	Venus passes 0.5° north of Regulus, 6 A.M. EDT
21	Asteroid Juno is at opposition, 4 A.M. EDT
22	Equinox (northern autumn/southern spring begins), 5 P.M. EDT
24	The Moon passes 0.8° north of Antares, 2 A.M. EDT
29	The Moon passes 3° north of Jupiter, 8 P.M. EDT
30	The Moon passes 3° north of Neptune, 9 A.M. EDT

2009
Oct

S	M	T	W	T	F	S
				1	2	3
●	5	6	7	8	9	10
◐	12	13	14	15	16	17
○	19	20	21	22	23	24
◑	26	27	28	29	30	31

2	The Moon passes 6° north of Uranus, 10 P.M. EDT
5	Mars passes 6° south of Pollux, 6 P.M. EDT
	Mercury is at greatest western elongation (18°), 10 P.M. EDT
8	Mercury passes 0.3° south of Saturn, 5 A.M. EDT
11	The Moon passes 1.2° south of Mars, 9 P.M. EDT
13	Venus passes 0.6° south of Saturn, noon EDT
16	The Moon passes 7° south of Saturn, 9 A.M. EDT
	The Moon passes 7° south of Venus, 3 P.M. EDT
21	Orionid meteor shower peaks
	The Moon passes 1.0° north of Antares, 11 A.M. EDT
27	The Moon passes 3° north of Jupiter, 5 A.M. EDT
	The Moon passes 3° north of Neptune, 5 P.M. EDT
30	The Moon passes 6° north of Uranus, 5 A.M. EDT
31	Asteroid Ceres is in conjunction with the Sun, 11 A.M. EDT

Venus dazzles before dawn



Venus' morning apparition starts to wind down this month, but not before the brilliant planet passes close to Saturn. *Astronomy*: Roen Kelly

Anytime Venus appears in the sky, it stands out. It shines at least 10 times brighter than the brightest star, and no other planet appears even half as bright. This year provides ample opportunities to view Venus and to see it through a telescope at all sizes and phases. One of Venus' 2009 highlights comes October 13, when the planet passes just 0.6° from Saturn before dawn.

As 2009 opens, Venus rides high in the evening sky. It reaches the peak of this apparition January 14, when it lies 47° east of the Sun. The planet then shines at magnitude –4.6, a brilliant counterpoint in the southwest to the bright winter stars rising in the southeast. Venus sets nearly 4 hours after the Sun.

Turn your telescope on Venus in mid-January, and you'll see a half-lit disk 24" across. During the next few months, Venus' orbit carries it between the Sun and Earth, so the planet's size grows and its phase dwindles.

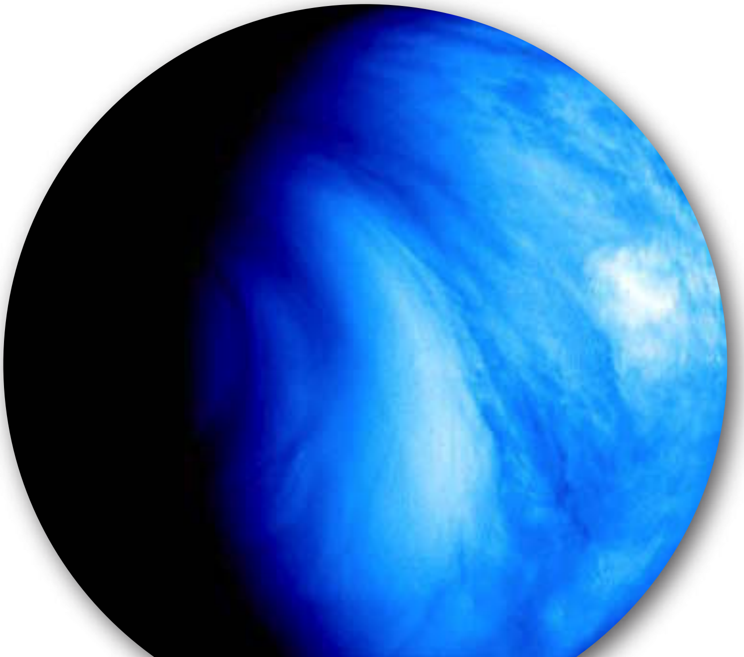
On February 19, Venus appears 39" across and barely one-quarter lit. It also shines brightest (magnitude –4.8) on this date. In mid-March, the planet reveals a 55"-diameter disk that's less than 10 percent illuminated.

Venus will disappear for most people around inferior conjunction March 27. But don't give up all hope. On that date, Venus lies 8° north of the Sun and rises 30 minutes before sunrise. With a clear sky and some luck, observers with telescopes might glimpse Venus' 59"-diameter disk, which appears just 1 percent lit. (Stop viewing before sunrise to prevent moving the Sun into your field of view.)

Venus reappears before dawn in early April. A crescent Moon occults the planet April 22, an event visible in much of North America. Through a telescope, Venus then appears 45" across and 17 percent illuminated.

Venus climbs higher as it approaches greatest western elongation June 5. It then rises 2 hours before the Sun and once again appears half-lit. On June 19, Venus passes 2° south of Mars, and a crescent Moon lies 5° above them.

As summer progresses, Venus sinks lower. It passes 1° south of the Beehive star cluster (M44) September 1. And on October 13, Venus passes 0.6° south of Saturn in the morning twilight. Venus finally disappears in the Sun's glow in late November.



Cloudy Venus shows little detail from Earth, but the ultraviolet-sensitive eyes of the Venus Express spacecraft reveal streaky clouds.
ESA/MPS/DLR-PF/IDA

Will the Lion roar again?

2009
Nov

S	M	T	W	T	F	S
1	○	3	4	5	6	7
8	◑	10	11	12	13	14
15	●	17	18	19	20	21
22	23	◐	25	26	27	28
29	30					

1	Venus passes 4° north of Spica, 9 P.M. EST	👁 🔭
5	Mercury is in superior conjunction, 3 A.M. EST	
9	The Moon passes 3° south of Mars, 1 A.M. EST	👁 🔭
12	The Moon passes 8° south of Saturn, 8 P.M. EST	👁 🔭
17	Leonid meteor shower peaks	👁
23	The Moon passes 4° north of Jupiter, 5 P.M. EST	👁 🔭
24	The Moon passes 3° north of Neptune, 1 A.M. EST	🔭
26	The Moon passes 6° north of Uranus, 1 P.M. EST	🔭

A pair of brilliant bolides trail smoke, overshadowing two fainter meteors in this photo of the 2001 Leonid shower. Tony and Daphne Hallas

Meteor showers in 2009

Name	Peak date	Moon's phase	Prospects
Quadrantids	Jan. 3	Waxing crescent	Excellent
Lyrids	April 22	Waning crescent	Excellent
Eta Aquarids	May 5	Waxing gibbous	Fair
Perseids	Aug. 12	Waning gibbous	Poor
Orionids	Oct. 21	Waxing crescent	Excellent
Leonids	Nov. 17	New Moon	Excellent
Geminids	Dec. 14	Waning crescent	Excellent

Meteor showers provide some of the most thrilling moments in observing. This year promises to be one of the best in recent memory, with many productive showers occurring during the dark of the Moon.

November's Leonid shower may be the finest. Astronomers predict enhanced rates this year, perhaps peaking at more than 100 meteors per hour the mornings of November 17 and 18. New Moon arrives November 16, perfectly timed for observing this exceptional shower.

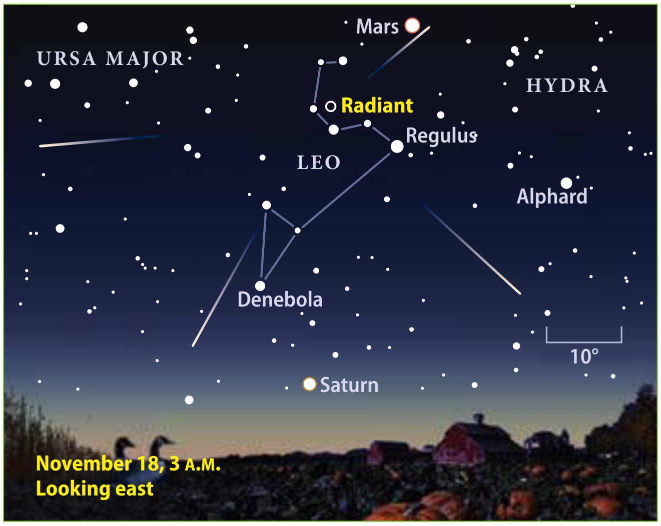
The Quadrantid shower gets the year off to a fine start. It peaks before dawn January 3, when rates should approach 100 meteors per hour. The waxing crescent Moon sets before midnight, leaving the prime predawn hours dark.

The year's warm-weather showers don't fare as well. A waxing gibbous Moon will shed unwanted light on May's Eta Aquarids' peak. And the Perseids, which peak August 12, have to fight a waning gibbous Moon.

The real stars of the meteor year come in the final 3 months. Although the Leonids lead the way, October's Orionids and December's Geminids also peak without a bright Moon.

The Orionids peak October 21, three days after New Moon. Observers normally see about 30 Orionid meteors per hour but counted nearly double that rate in 2006 and 2007. Let's hope the trend continues in 2009.

The Geminids reach maximum December 14, 2 days before New Moon. Expect rates to peak near 100 meteors per hour. This shower ranks among the most consistent from year to year.



November 18, 3 A.M.
Looking east

The 2009 Leonid shower suffers no Moon interference and boasts rates that may exceed 100 meteors per hour. *Astronomy*: Roen Kelly

2009
Dec

S	M	T	W	T	F	S
		1	●	3	4	5
6	7	◐	9	10	11	12
13	14	15	○	17	18	19
20	21	22	23	◑	25	26
27	28	29	30	●		

6	The Moon passes 6° south of Mars, 10 P.M. EST
10	The Moon passes 8° south of Saturn, 6 A.M. EST
14	Geminid meteor shower peaks
18	The Moon passes 1.4° north of Mercury, 3 A.M. EST
	Mercury is at greatest eastern elongation (20°), noon EST
19	Jupiter passes 0.6° south of Neptune, midnight EST
21	The Moon passes 4° north of Jupiter, 10 A.M. EST
	The Moon passes 4° north of Neptune, 10 A.M. EST
	Solstice (northern winter/southern summer begins), 1 P.M. EST
23	The Moon passes 6° north of Uranus, 9 P.M. EST
24	Pluto is in conjunction with the Sun, 1 P.M. EST
31	Partial lunar eclipse, 2 P.M. EST

A year-end lunar treat

The final day of 2009 brings the year's best eclipse of the Moon. That's the good news. The bad: 2009 has no total lunar eclipses. On December 31, Earth's dark umbral shadow covers, at maximum, just 8 percent of the Moon's disk. Residents of Europe, Asia, Africa, and Australia will get the best view.

In North America, those in the northwest will see the beginning of the eclipse, and those in the northeast will see the eclipse end. Earth's lighter penumbral shadow first touches the Moon at 17h15m Universal Time (UT), or 8:15 A.M. AKST. The umbral shadow reaches the Moon at 18h52m UT (9:52 A.M. AKST).

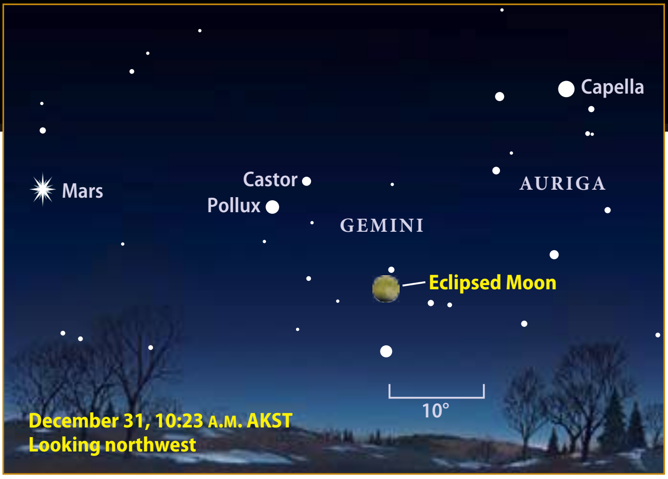
The umbra crosses the Moon's southern limb for 62 minutes. Although just 8 percent of the Moon lies in the dark shadow at maximum, the entire Moon lies within the penumbral shadow. This means the Moon's northern part also appears significantly darker than at a normal Full Moon.

Earth's umbral shadow leaves the Moon's surface at 19h54m UT (10:54 A.M. AKST; 2:54 P.M. EST), and the penumbral shadow bids the Moon adieu at 21h30m UT (12:30 P.M. AKST; 4:30 P.M. EST).

Although 2009 comes up short in the quality of its lunar eclipses, it doesn't lack for quantity. The Moon crosses Earth's penumbral shadow three other times: February 9, July 7, and August 5/6. Sharp-eyed observers will see the Full Moon grow darker.

February 9 offers the deepest penumbral eclipse. At maximum, 92 percent of the Moon is in Earth's outer shadow. Those in western North America will see most of this eclipse.

On July 7, 18 percent of the Moon falls within the penumbral shadow. Viewers in most of North America can watch this eclipse. The eastern two-thirds of North America will witness the August 5/6 eclipse. At its peak, the shadow covers 43 percent of the Moon.



The Full Moon crosses Earth's shadow December 31, bringing a partial eclipse to people in Alaska and the Eastern Hemisphere. *Astronomy*: Roen Kelly

Earth's shadow covers the Moon's north pole during a September 2006 eclipse. This month, our shadow darkens the south pole. Anthony Ayiomamitis

The Red Planet returns

Mars' north polar cap is on display when the planet reaches opposition this month. Steve Lee (University of Colorado)/Jim Bell (Cornell University)/Mike Wolff (SSI)/NASA

As 2010 begins, Mars stands on the threshold of opposition and peak visibility. On January 1, you can spy it climbing in the east during midevening. It then shines at magnitude –0.8, far brighter than the stars of its host constellation, Leo the Lion. It lies directly above Leo's brightest star, 1st-magnitude Regulus.

During the next 4 weeks, Mars swings westward into Cancer and grows noticeably brighter. When it reaches opposition January 29, it shines at magnitude –1.3 — nearly the equal of Sirius. Mars' ruddy glow sets it apart from whitish Sirius, which lies 50° to the planet's right.

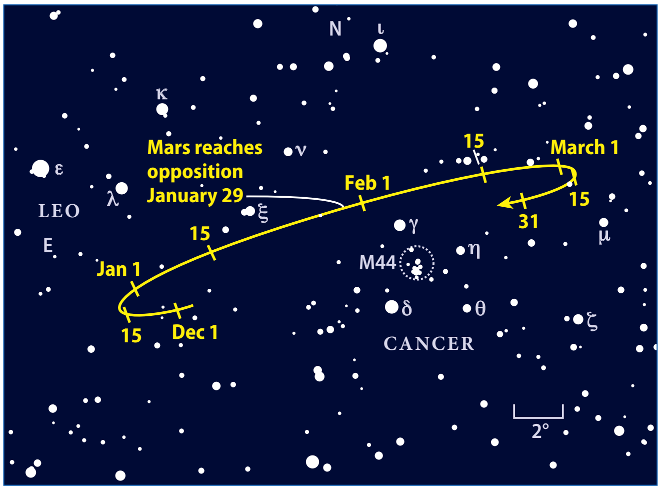
The weeks around opposition are best for viewing Mars through a telescope. Experienced observers know that Mars should be at least 10" across to show much detail in modest scopes. The planet reaches this diameter December 2, then grows to 14" across by opposition. Mars' diameter remains above 10" until March 22.

Throughout this prime observing season, Mars' northern hemisphere tilts toward Earth. It's spring in that hemisphere, so observers will have great views as the northern polar cap shrinks under the warming Sun. The cap will appear as a bright white spot.

For observers with good memories, the Red Planet's 14"-diameter disk will seem small in comparison to the previous few oppositions. In December 2007, Mars appeared 16" across. And three oppositions ago, in August 2003, it was 25" across. The differences arise because Mars follows a significantly elliptical orbit. When opposition comes near Mars' closest point to the Sun (as it did in 2003), the planet appears large. If opposition arrives when Mars lies farthest from the Sun, as it will in March 2012, the planet appears small.

Although Mars peaks in January, you can follow its motion throughout the latter half of 2009. A good time to start is June 19, when Venus passes 2° south of Mars in the morning sky. Venus then shines more than 100 times brighter than Mars.

Mars crosses Taurus and Gemini in late summer and early fall, then enters Cancer in mid-October. It traverses the Beehive star cluster (M44) from October 30 to November 2. Mars reaches Leo at the start of December before heading back to Cancer in early January. It passes the Beehive again in early February, this time some 3° north of the cluster.



The Red Planet lies near the Beehive star cluster (M44) in Cancer when it shines brightest in the winter sky. *Astronomy*: Roen Kelly

2010 Jan

S	M	T	W	T	F	S
					1	2
3	4	5	6	◐	8	9
10	11	12	13	14	○	16
17	18	19	20	21	22	◑
24	25	26	27	28	29	●
31						

3 The Moon passes 7° south of Mars, 7 A.M. EST

Quadrantid meteor shower peaks

4 Mercury is in inferior conjunction, 2 P.M. EST

6 The Moon passes 8° south of Saturn, 2 P.M. EST

11 The Moon passes 1.1° north of Antares, 8 A.M. EST

Venus is in superior conjunction, 4 P.M. EST

13 The Moon passes 5° south of Mercury, 11 A.M. EST

15 Annular solar eclipse, 2 A.M. EST

17 The Moon passes 4° north of Neptune, 6 P.M. EST

18 The Moon passes 5° north of Jupiter, 5 A.M. EST

20 The Moon passes 6° north of Uranus, 6 A.M. EST

27 Mercury is at greatest western elongation (25°), 1 A.M. EST

29 Mars is at opposition, 3 P.M. EST

30 The Moon passes 7° south of Mars, 3 A.M. EST

2010 preview

Looking ahead to next year...

Mars gets 2010 off to a fine start, shedding its warm light on the frigid landscape. But the Red Planet is just the opening act in a year that provides great views of many solar system objects. Venus will dominate evenings from March until October. But Jupiter could be a bigger story. When it reaches opposition in September, it will lie closer to Earth — and thus appear bigger through a telescope — than at any time since 1963.

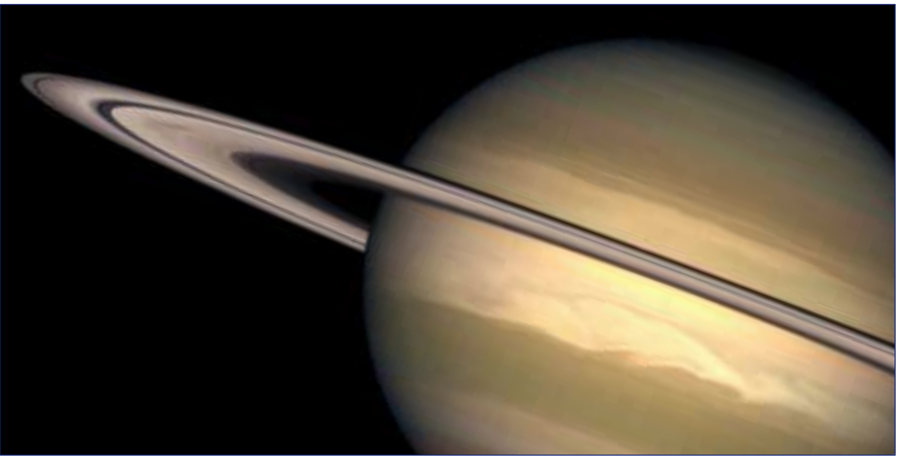
But to most observers, the highlight of planet-viewing in 2010 will be the return of Saturn's rings. Following 2 years when the rings were nearly edge-on to our line of sight, seeing the rings open will be a thrill. The rings will tilt 4° at opposition in March and stretch out to 12° by year's end.

We haven't seen a total lunar eclipse since February 2008, but the wait ends December 20/21. North Americans will see all 73 minutes of totality. And because the eclipse comes on the winter solstice, the eclipsed Moon will lie high in the sky.

The Sun also gets in on the eclipse act. January 15's annular eclipse crosses central Africa, southern India, and eastern Asia. At maximum, observers will see a ring of sunlight for more than 11 minutes.

July 11 brings a total solar eclipse. Although not as long as 2009's China eclipse, this event offers more than 5 minutes of totality. Most of the path lies in the Pacific Ocean, although it does cross Easter Island and southern South America.

A total lunar eclipse, the first in nearly 3 years, graces our skies December 20/21. Dan Rodgers



Saturn's rings return to prominence in 2010, following a year when they were tilted edge-on to our line of sight. NASA and the Hubble Heritage Team (STScI/AURA)

A total solar eclipse brings darkness at midday July 11. Unlike the July 2009 eclipse, which crosses heavily populated India and China, most of the 2010 path lies in the Pacific Ocean. Leslie Marczi